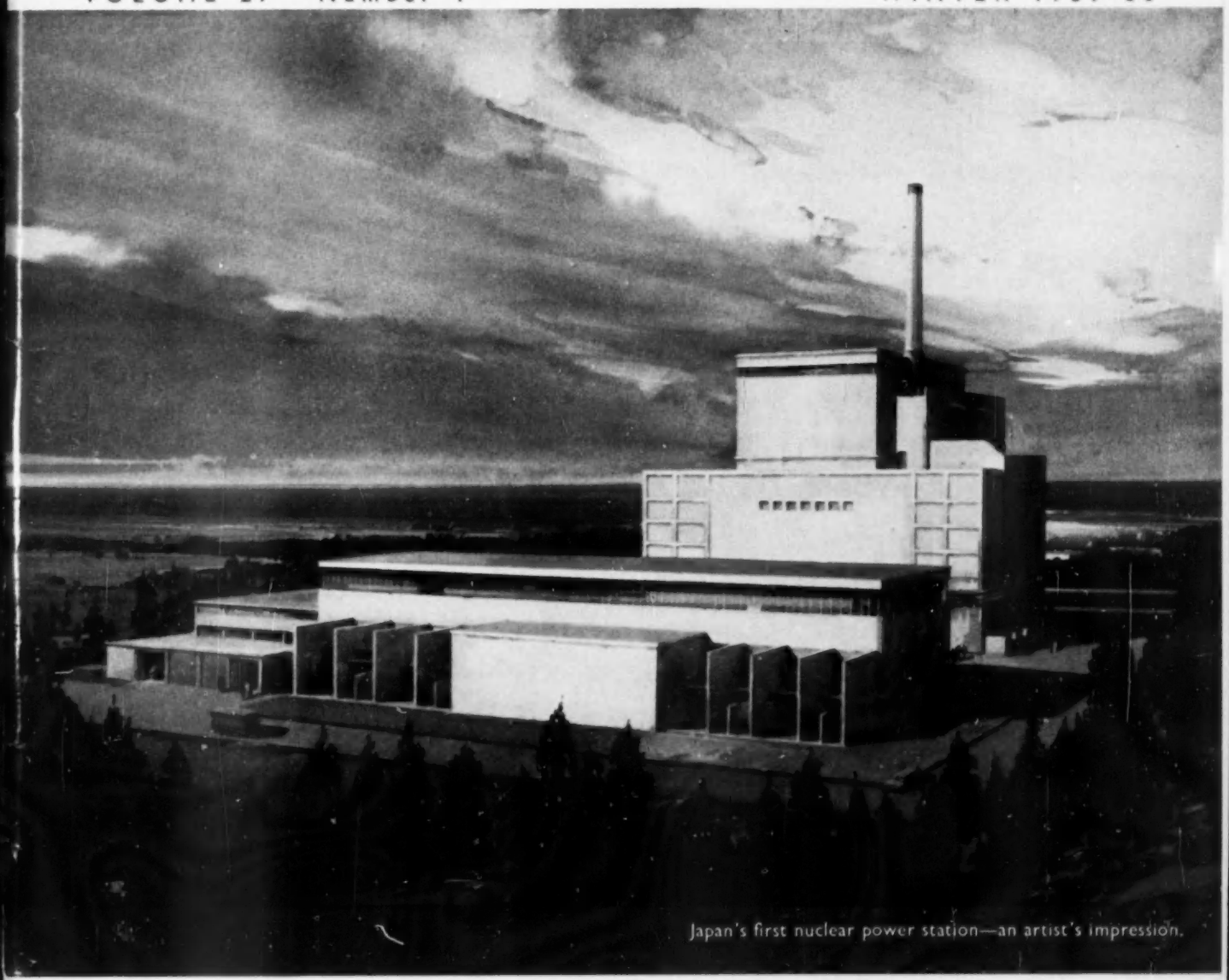
G.E.C. JOURNAL

VOLUME 27 Number 1 WINTER 1959-60



Japan's first nuclear power station—an artist's impression.

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

Volume 27, number 1

WINTER, 1959-60

G.E.C. JOURNAL

CONTENTS

Page

2 Frontispiece—Mr. D. Yasukawa, President of the Japan Atomic Power Company, signing the contract for the Tokai-Mura nuclear power station

PROGRESS 1959

3 Research
4 Nuclear Power
6 Heavy Engineering
16 Power Distribution
22 Transport
29 Lamps and Lighting
37 Telecommunications

42 Re-motoring a Continuous Strip Mill
By J. T. Mills and S. A. G. Emms

49 The G.E.C. Cross-Flow Fuel Element
By M. C. Hartnell-Beavis

55 330 kV Oil-filled Cables for Snowy Mountains Hydro-electric Scheme
By A. N. Arman

59 Technical Literature

Published by
THE GENERAL ELECTRIC CO. LTD.
Magnet House, Kingsway, London, W.C.2

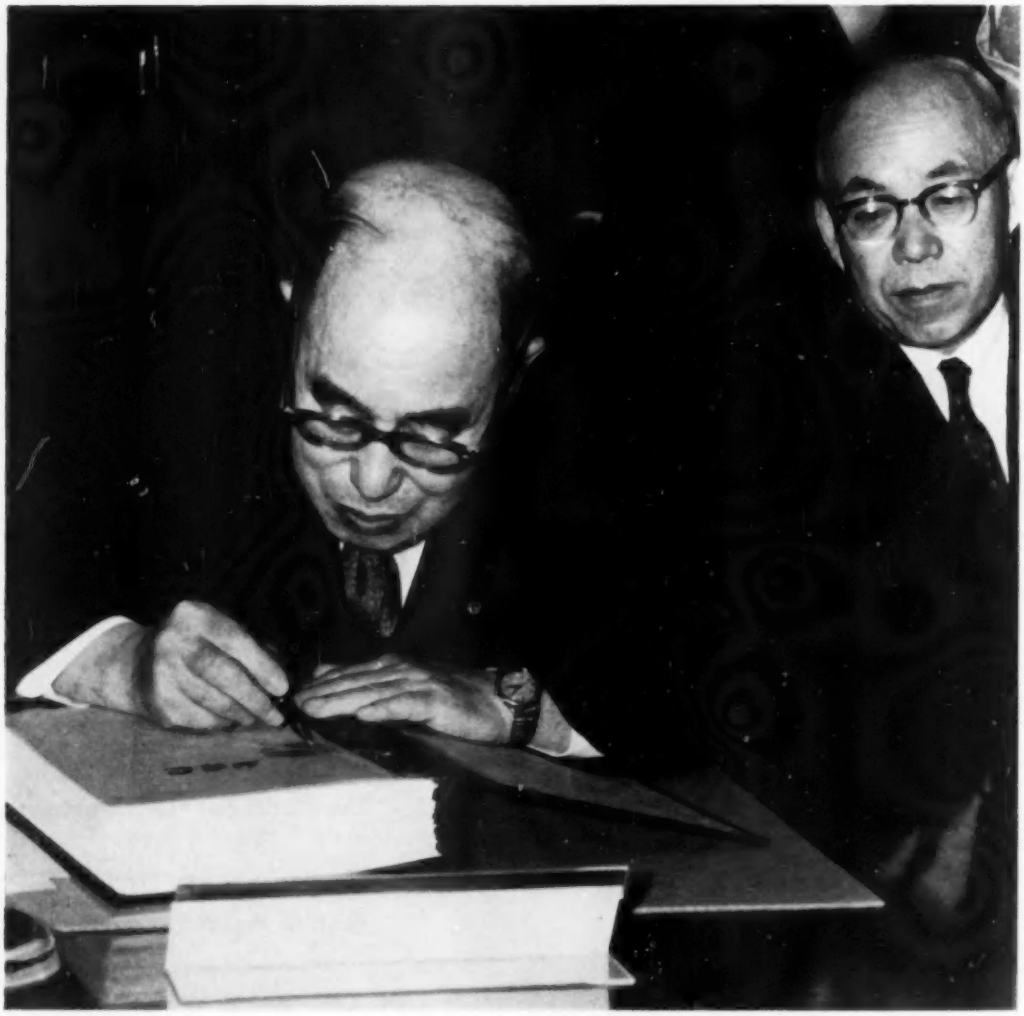
Copyright

REPRINTING and PHOTO-COPYING
Material appearing in this Journal may be reprinted provided that the source is given and provided that permission for such reprinting is sought from the Editor.
No permission is required for the making of copies of individual articles; it is only requested that such copies should also quote the source of the material.

Printed by The Hollen Street Press, Ltd., London, W.1

COVER PICTURE

An artist's impression of the 150 MW nuclear power station, Japan's first, which the G.E.C. is to build at Tokai-Mura, 70 miles from Tokyo.



Mr. D. Yasukawa, President of the Japan Atomic Power Company, signing the contract with the G.E.C. for the construction of Japan's first nuclear power station at Tokai-Mura. The signing ceremony took place in Tokyo on December 22, 1959.

Research

Research has continued on the broad front necessary to support the Company's very varied activities—in such newer fields as semiconductors, microwave valves, computers and nuclear engineering no less than in the well-established areas such as lamps, lighting, domestic equipment and aerodynamics. Important though it is that research should continue in many of the present fields of activity to keep pace with advancing technology, it is in the breaking of new ground that its really valuable contributions are made. For this reason increasing emphasis has been placed on fundamental and exploratory research.

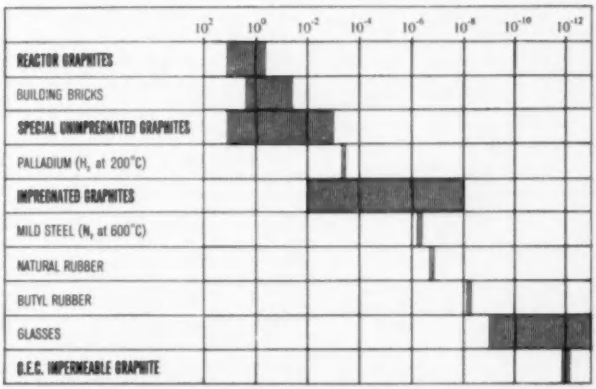


Table 1.—Comparative permeability of materials used for nuclear reactor applications (ml helium (stp) per sec through 1 cm cube with one atmosphere pressure difference).

In contradistinction to the objective research required to support development programmes, fundamental research is largely unplanned and its outcome is predictable only in the broadest terms. Not all such research is rewarding, except in the sense that no addition to knowledge is wasted, but the points of break-through cannot be accurately foreseen. Much of the fundamental research has been directed towards materials, to the better understanding of those already known, and to the discovery of new ones. Many successes have been achieved.

New microwave ferrites have been prepared for use in telecommunication systems, particularly in non-reciprocal devices in trunk radio equipment. Research on magnetic thin films emphasizes their great potential use as the basis of quick-access stores in digital computers, with advantages of much higher speed and lower cost than conventional storage systems.

New semiconductor materials of special types have been discovered, giving the Company a leading position in thermoelectric cooling. They may also be applicable to the generation of electricity.

The discovery of impermeable forms of graphite opened new possibilities in nuclear reactor engineering. On the one hand the development has been taken to the stage where plant for the production of 120 000 fuel element sleeves for the Hunterston and Japanese reactors has been built. On the other hand the development of a completely impermeable graphite has reached the stage where its use as a canning material for nuclear fuel appears attractive (Table 1).

Studies of the properties of materials in a state of extreme purity, and of the effect of controlled additions of insoluble additives, are beginning to yield interesting results.

Research in the hot-cathode gas-filled valve field has demonstrated the feasibility of operating rectifiers and thyratrons at peak currents exceeding 10 000 amperes with anode voltages up to 50 kV.

An entirely different field of fundamental research has resulted in an important new microwave valve, the Ophitron. It has advantages of very small size and weight, combined with a wide band output of low noise factor, and the facility of simple electronic tuning, which offer many useful applications in the microwave field.

Progress 1959

Nuclear Power

JAPAN.

Perhaps the most notable G.E.C. achievement during 1959 has been the winning of the contract to build Japan's first nuclear power station. On December 22, 1959, the Japan Atomic Power Company signed a £20 million contract with G.E.C. for a 150 MW nuclear station to be built at Tokai-Mura, approximately seventy miles north-east of Tokyo. The station will be complete in 1964.

The first of these is with the Fuji Electric Manufacturing Co. Ltd., the leading company of a consortium of seventeen companies in Japan known as the First Atomic Power Industrial Group (F.A.P.I.G.). These companies will play a leading part in the construction of the 150 MW nuclear power station to be built at Tokai-Mura.

The second overseas nuclear agreement is with Maschinenfabrik Augsburg-Nürnberg A.G. (M.A.N.)

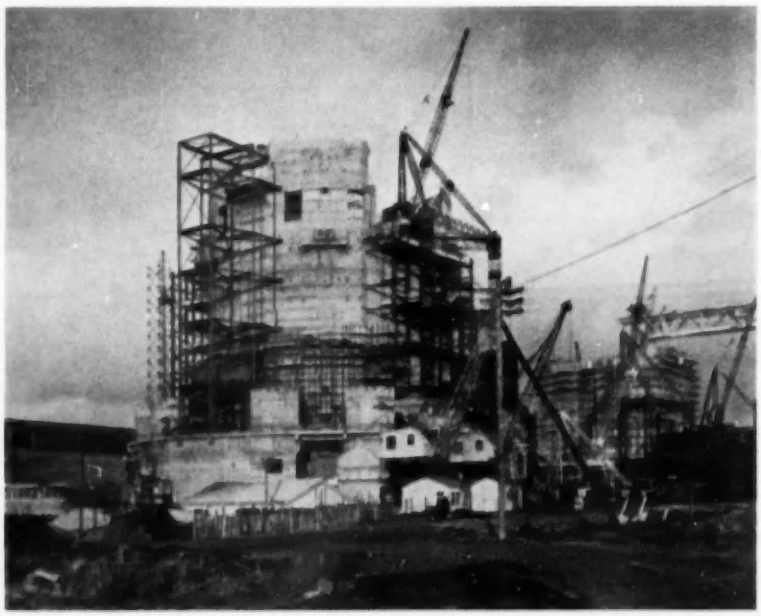


Fig. 1.—Reactor "A" under construction at Hunterston, with the turbine hall at the back to the left and Reactor "B" to the right.

The design, which was submitted in collaboration with Simon-Carves Limited, is for a single-reactor station, and is of particular interest in view of the special measures taken to ensure the safety of the installation under earthquake conditions.

G.E.C. is the main contractor for the reactor unit and generating plant, and a new Company, the British General Electric Company of Japan, has recently been formed to handle the contract in Tokyo.

COLLABORATION AGREEMENTS.

Two long-term nuclear power collaboration agreements have been concluded which will license overseas companies to build plant to G.E.C. designs.

of Germany. This agreement, which is initially for a period of ten years but is capable of extension, was signed at Nuremberg in May, 1959.

HUNTERSTON.

Progress on the 320 MW nuclear generating station at Hunterston continues after a series of labour disputes which have now been settled. Vessel fabrication work on the site was temporarily brought to a complete standstill, but rephasing of the construction programme enabled work on the rest of the station to be continued without too much interruption.

Civil-engineering work on both reactors and on the turbine hall is far advanced, and considerable progress

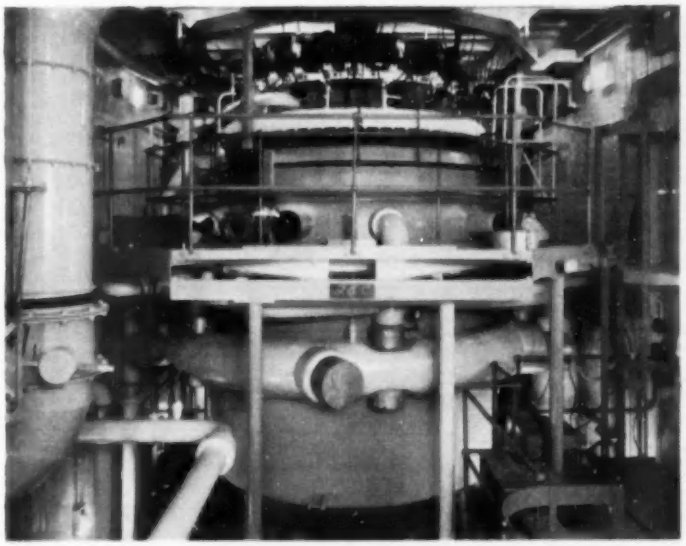


Fig. 2.—" Zenith "—the zero-energy high-temperature gas-cooled reactor constructed for the U.K.A.E.A. at Winfrith.

has been made with the circulating-water system. A number of the smaller buildings on site are in various stages of construction. Among these, the administration and welfare blocks are expected to be occupied by members of the permanent station staff in the spring of 1960.

" ZENITH " PROJECT.

Towards the end of 1959, work was completed on " Zenith ", the zero-energy reactor which the Company has built for the United Kingdom Atomic Energy Authority at Winfrith in Dorset. The reactor (fig. 2) was put into operation for the first time in December, and final commissioning by the Authority is now in progress.

It will be recalled that " Zenith " is the precursor of " Dragon ", the high-temperature gas-cooled reactor experiment which is being undertaken as a joint project by the members of the European Nuclear Energy Agency.

MARINE REACTOR DESIGN.

Early this year details were announced of an advanced type of gas-cooled graphite-moderated reactor proposed in the first instance for ship propulsion. A radically new type of fuel element, consisting of uranium-dioxide pellets in stainless-steel cans arranged at right angles to the flow of cooling gas, enables much higher fuel temperatures to be used and a much greater amount of heat to be extracted from a given volume. This leads to a very compact system, and a complete reactor unit producing 20 000 s.h.p. is contained in an outer vessel only 44 ft long, 35 ft wide, and 37 ft high. A full description of the new fuel element is given on pages 49-54 of this issue.

Economic comparisons with conventional engines indicate that for some applications this nuclear system would produce definite savings.

RESEARCH AND DEVELOPMENT.

Throughout the year, the research and development department has been heavily occupied on a great number of problems, some specific to particular designs and others of more general application. Most of the work has been concerned with gaining more knowledge on the individual components of the Hunterston station and with solving design problems for the Tokai-Mura reactor, but much attention has also been given to other projects, particularly the more advanced designs put forward for marine propulsion.

Wherever possible, experiments have been planned to give results for a range of variables, so that the data obtained will be of use in future designs as well as those currently being developed.

POWER MANIPULATOR.

During 1959, early assessments of the interest shown in the Power Manipulator, first introduced early in 1958, were substantiated by the receipt of orders for four further machines.

Two of these were for research stations overseas, one in Sweden and the other in Japan. The others are for the Atomic Energy Research Establishment at Harwell, and for the new nuclear laboratories of the Central Electricity Generating Board at present being constructed at Berkeley, Gloucestershire. As a result of experience and continued development work, a number of improvements have been incorporated in the designs of these machines. Discussions are continuing on a number of other enquiries that have been received.

Progress 1959

Heavy Engineering

GENERATING PLANT.

During the year under review work has continued on the design and development of large reheat turbo-alternators, including tandem-compound machines for operation at super-critical steam pressures.

Two 200 MW turbo-alternators having steam conditions of 2 350 lb/in², 1 050 deg. F at the turbine stop valve with reheat to 1 000 deg. F, will be installed in extensions to the Kincardine Power Station of the South of Scotland Electricity Board and are the largest so far ordered for a Scottish power station. The first machine is due for commissioning in time to take the winter load of 1962.

An important order received from the C.E.G.B. is for the last two of the six 120 MW hydrogen-cooled turbo-alternators for Northfleet Generating Station, where the first set has now been commissioned. The alternator of this machine, fig. 2, was subjected to an exhaustive series of tests at the works, both in air and in hydrogen at pressures of up to 45 lb/in², and loads of up to 120 MVA (corresponding to full-load excitation) were attained with the existing test equipment. Extensions to the testing facilities to enable the present maximum loading to be doubled are expected to be in commission towards the end of 1960, and further extensions are being planned.

Some interesting tests have also been carried out on a hydrogen-cooled alternator for Wallerawang Power Station (Australia), for which the Company is building two 60 MW turbo-alternators. These tests included a sudden-short-circuit applied at 110 per cent voltage and subsequent examination of the windings showed that the machine was fully capable of withstanding this drastic treatment.

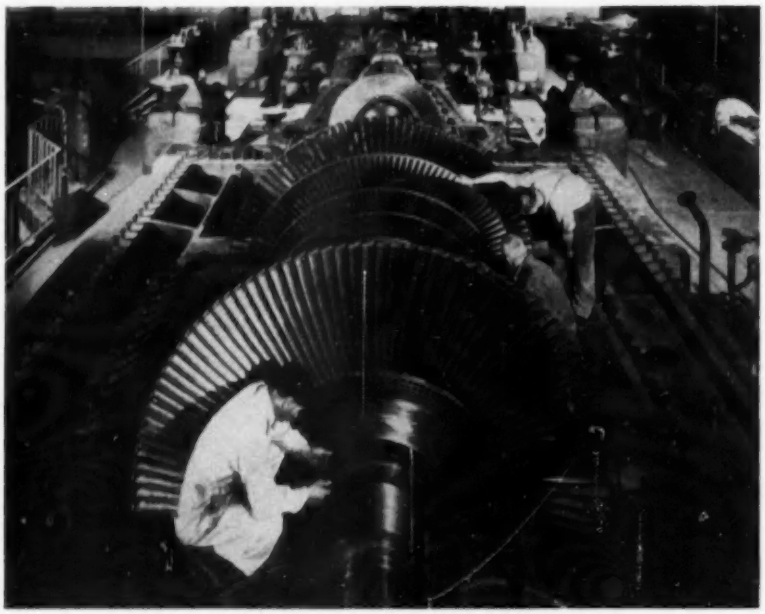


Fig. 1.—120 MW turbo-alternator in course of erection at the Northfleet Power Station of the C.E.G.B.

The first of two 30 MW air-cooled turbo-alternators for the Mica Creek Power Station at Mount Isa Mines (Australia) is in an advanced state of erection on site and is due for commissioning early in 1960. In South Africa two 30 MW sets, Nos. 4 and 5 in a station of six such machines, were commissioned at the Kelvin " A " Power Station of Johannesburg Municipality, while two 60 MW sets are now in course of manufacture for the Kelvin " B " Station. At home, the first two of three 60 MW sets for the C.E.G.B. Bold " B " Generating Station, near St. Helens, have been commissioned and the third set is in course of erection.

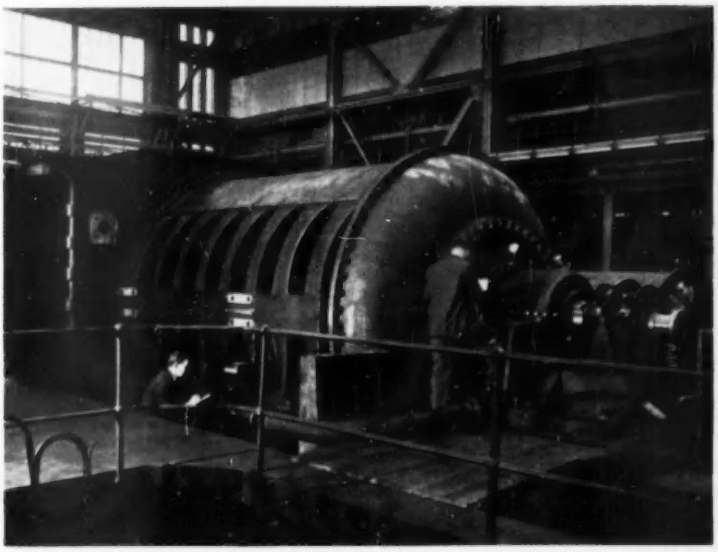


Fig. 2.—120 MW hydrogen-cooled alternator erected for test.

In the industrial field at home, a contract has been received for extensions to the power station at the Ravenscraig Works of Colvilles Ltd. These extensions will include two turbo-alternators designed to operate at unusually low power factors so as to provide reactive kVA for the steelworks load. The first machine is rated at 12 MW, 28 MVA and the second at 20 MW, 30 MVA. A special excitation system incorporating magnetic-amplifier voltage regulators will be provided to cope with rapid changes in loading. The contract includes the associated generator-transformers and switchgear, together with a turbine-driven blower with a duty of 90 000 ft³/min at 30 lb/in². The Company is responsible for the complete extension, including a 200 K lb/h boiler, civil works and auxiliary services. Two turbine-driven blowers, each rated at 80 000 ft³/min at 25 lb/in² have been ordered by the South Durham Iron & Steel Company, and industrial machines commissioned include 6 MW pass-out turbo-alternators for Stanton Iron Works and New Merton Board and Paper Mills and a turbine-driven compressor for Shellhaven Refinery.

At the National Gas Turbine Establishment at Pyestock, the first three of eight compressor-exhauster sets have now been put into service. Each of the sets is run up to speed by an 8 000 h.p. turbine and driven by a 36 000 h.p. synchronous motor. The need for large quantities of air at very low temperatures for aeronautical research at Pyestock has been satisfied by the commissioning of a 5 MW air-driven turbo-alternator which exhausts at a temperature of −73 deg C.

As a result of the current trend in power station practice towards large generating units, motors of greater power are needed for the associated auxiliary drives. For example, the six 11 kV a.c. machines now being built for the boiler feed pump drives at Thorpe Marsh Power Station are rated at 7 900 h.p., and are believed to be the largest 2-pole variable-speed slipring motors to be built in Great Britain.

Developments arising from this change include the designing of equipment for the recovery of the slip power of large induction motors, and plans for a slip-power recovery scheme for a 6 500 h.p. boiler feed-pump drive are at an advanced stage. Full-load tests on such large machines in the manufacturer's works can be both difficult and costly, and to overcome these objections a new test plant has been installed.

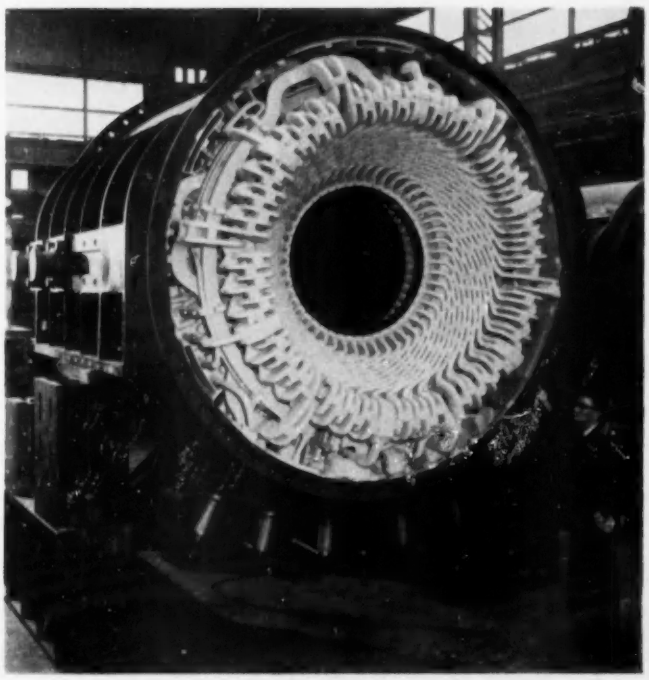


Fig. 3.—Water-cooled stator for 60 MW alternator.

The plant embodies a differential gearbox rated for 10 000 h.p. at 3 000 rev/min and the test is conducted on the back-to-back principle in which two motors are tested simultaneously. A variable-speed d.c. motor feeding into the planetary gear of the unit creates the required speed difference between the two motors on test. In effect, one motor is braked and develops a torque, while the other is accelerated, absorbs the torque of the slower-running machine, and delivers power as an induction generator. The d.c. motor driving the differential shaft provides the slip power or the rotor losses, and the only power taken from the a.c. supply is that required to cover the stator losses. The new test plant is illustrated in fig. 5.

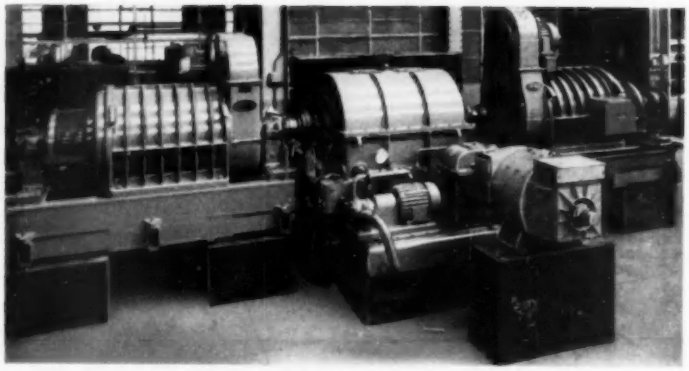


Fig. 5.—New test plant for large induction motors.

GENERAL ENGINEERING

The period under review has been one of intense activity in the production of winding engines and sixteen electric winders have been commissioned during this time, four of them overseas and twelve in the U.K. for the National Coal Board. Among those put into service overseas was a 4-rope friction winder at the No. 5 shaft of the West Driefontein Gold Mining Co. Ltd., which hoists a load of 15 tons from a depth of 5 460 ft. A similar winder is also in operation at the Stilfontein Mine of the General Mining and Finance Corporation ; this hoist is of particular interest as it is one of the few very large hoists to employ roller bearings for the drum and pinion shafts. Perhaps the most interesting installation for the National Coal Board was the changeover at Littleton Colliery where a new double-drum clutched winder was installed in the remarkably short time of ten days during the miners' annual holiday.

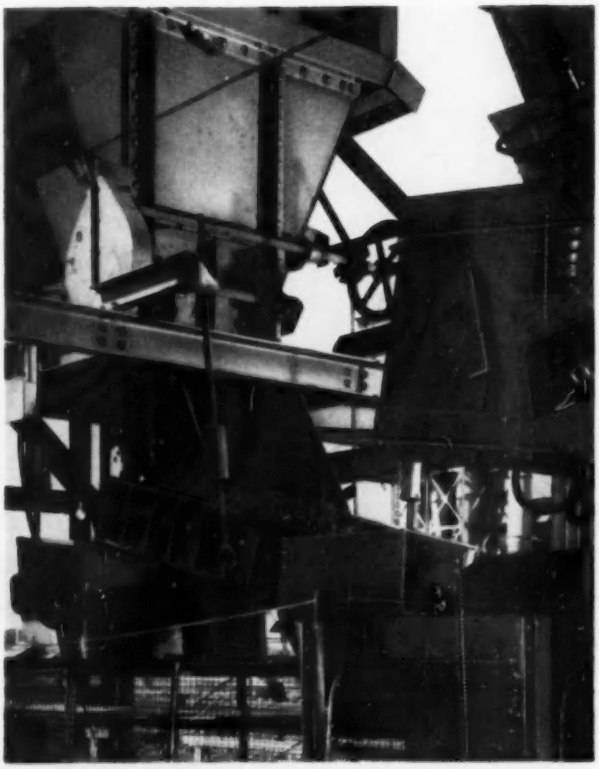


Fig. 4.—" Sherwen " 30 in. × 5 ft feeder handling 50 ton/h of minus ¾ in. coke at the Abbey Works of the Steel Company of Wales.

The number of orders received has been maintained at a satisfactory level and, in all, twenty-three winders have been placed on order, five of them being destined for overseas mines. Two for the National Coal Board are of unusual interest in that grid-controlled mercury-arc rectifier-inverters are used to provide the speed control system. The first of these winders is rated at 1 490 h.p. and is to be installed at Birch Coppice Colliery in the Midlands Division. The second, which is rated at 2 500 h.p., is for Shirebrook Colliery in the Nottingham Division.

The development of electric winders has continued apace and considerable effort has been devoted in particular to the detailed design of the " Blair " winder on order for the President Steyn Gold Mining Company Ltd. of Anglo American Corporation, South Africa. Like several other winders, it will be equipped with the new G.E.C. high-pressure braking system.

During the year, one of the largest single-unit coal preparation plants in this country was commissioned at the Hawthorn Combined Mine of the National Coal Board. This plant is illustrated on page 10.

A smaller plant, of 350 ton/h capacity, has been put into service at the Desford Colliery and another is in course of erection at Metropolitan Colliery, N.S.W., Australia. From South Africa orders have been received for plants for Landau and Kilbarchen Collieries, with hourly capacities of 350 and 330 short tons respectively.

Several large contracts for materials handling plant and equipment are in hand, the largest being for a complete preparation plant for the Redbourn Works of Richard Thomas & Baldwins Ltd., at Scunthorpe, which will have an annual throughput of $1\frac{3}{4}$ million tons. The Company is also supplying equipment for a sinter plant at the United Steel Company's Works at Workington as well as three large wagon tipplers for extensions being carried out by the South Durham Iron & Steel Company.

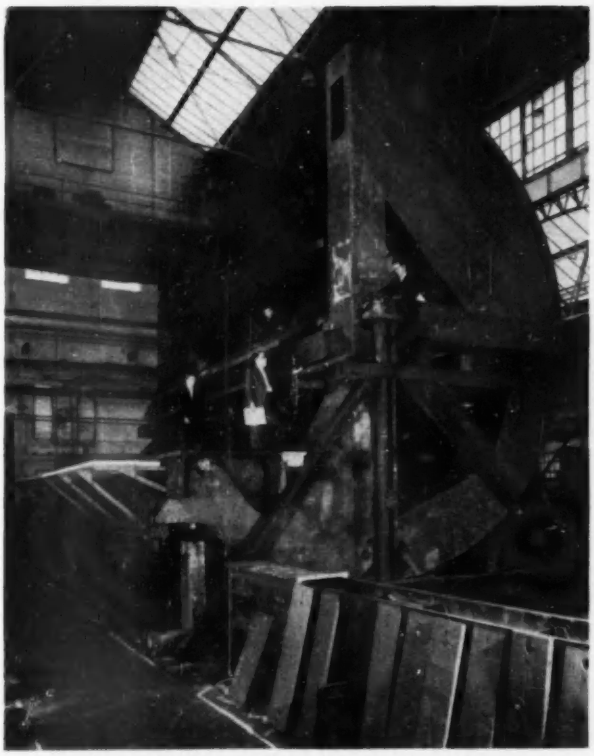


Fig. 6.—50-ton wagon tippler in course of erection.

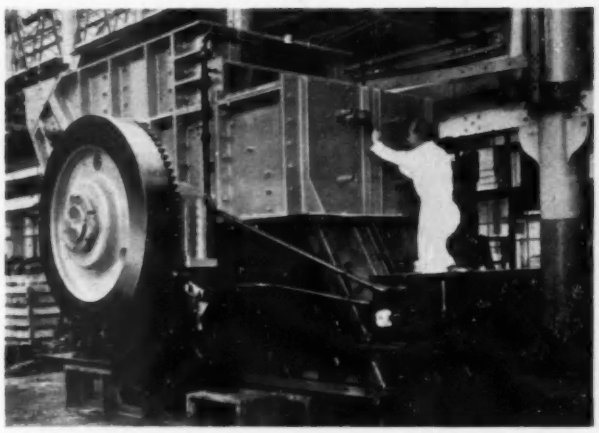


Fig. 7.—72 in. × 60 in. Pennsylvania Dixie Non-Clog Hammermill.

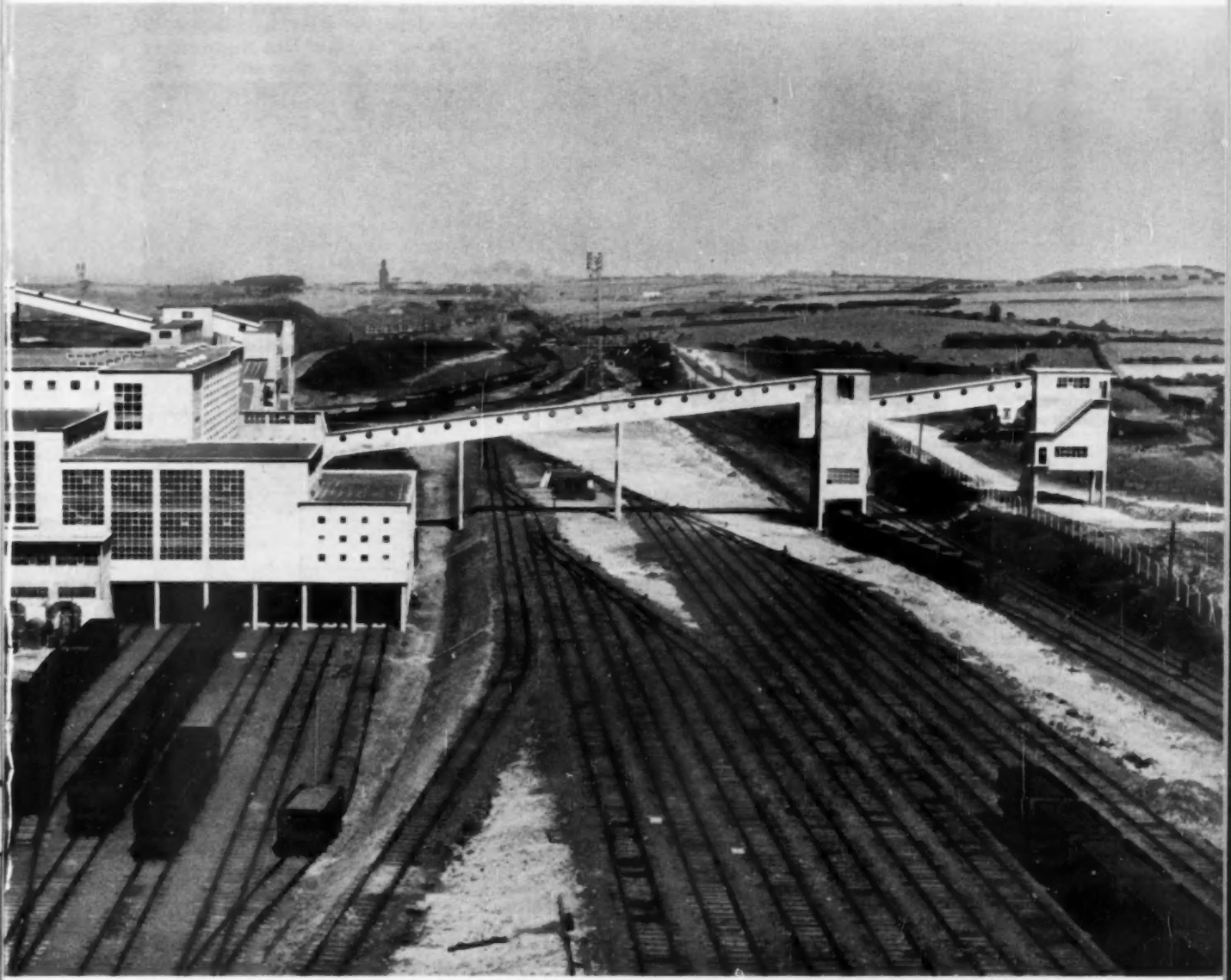
Fig. 8.—16 kW electric magnet raising a 12-ton ingot at the Ebbw Vale works of Richard Thomas & Baldwins Ltd.

Among the projects completed during the year may be mentioned the ore blending plant at the Stanton Ironworks Company near Nottingham and, overseas, an ore blending plant in Belgium as well as a stocking and reclaiming plant at Pepel for the Sierra Leone Development Co. Ltd.

The demand for standard items from the wide range of crushing and processing machinery made by the Company has continued. Contracts placed with the Company have included a 72 in. × 60 in. Dixie Hammermill for Adelaide Cement Co., South Australia—the largest ever built—and a 60 in. × 60 in. Pennsylvania

Coal Preparation Plant

One of the largest single-unit coal preparation plants in the U.K. is at Hawthorn Combined Mine in the Durham Division of the National Coal Board. In this plant 750 ton/h of run-of-mine coal from neighbouring collieries is cleaned by the G.E.C. two-process system.



Efficient separation at low operating costs is achieved by a combination of the Chance sand and froth flotation processes. One of the two Chance cones is fitted with a middlings column to enable efficient two-gravity separation to be achieved in a single cone.

Fig. 9.—Part of the new mineral dressing laboratory at Erith.

Dixie Mill for an Associated Portland Cement Manufacturers' plant in Nigeria. Other orders include one from Babcock & Wilcox for three pressurized hammermills destined for Japan.

The year has seen the transfer of the ore dressing laboratory from Wembley to Erith Works, where its facilities have been extended. The sales, engineering, and manufacture of electric furnaces is now also centred at the Erith Works where, in addition to the design and manufacture of the more orthodox types of furnace equipment, development is proceeding on vacuum furnaces and induction heating equipment.

Intermittent electric furnaces have now been installed at Parkhall Pottery to replace the coal-fired bottle furnaces. The bottle furnace, once a common sight in the Potteries, was very inefficient and the advent of the electric furnace has considerably increased efficiency and has enabled the production of ceramics to be accurately controlled.

CONVERTING PLANT.

The work of the past twelve months includes some noteworthy examples of standard air-cooled pumpless steel tank rectifiers, as well as the grid-controlled versions. Among the applications of free-firing rectifiers should be mentioned the delivery of the first of seventeen 2 500 kW 750 V equipments for Phase II of the Kent extension of the British Railways Southern Region electrification. Of historical interest is the replacement of two 2 000 A water-cooled rectifiers installed at Upney Lane Substation of London Transport by standard pumpless rectifiers, the work being completed within five weeks of the order being received.

The grid-controlled mercury arc rectifier continues to play an important part in large industrial applications, outstanding examples being the 19·8 MW installation at the Ebbw Vale Works of Richard Thomas & Baldwins Ltd., and the 10 MW installation at the Shotton Works of John Summers Ltd. An interesting equipment in which grid control is used in conjunction with on-load tap changing has been supplied to the Cellulosa Argentina plant in South America, where two 4 200 kW rectifiers with a total output of 12 000 A are used for the production of chlorine by an electrolytic process. New and improved methods embodying the latest servo-electronic techniques continue to be developed for providing high speed, high accuracy response of the grid control.

Single-anode mercury arc rectifiers of the air-cooled pumpless type with grid control continue to be applied to printing press drives manufactured by Witton-James Ltd., and for this purpose a new 1·3 type of rectifier has been produced capable of 700 A from 6 cylinders at 550 volts. The new rectifier not only gives a larger output than the previous type but is actually physically smaller.

Mention has previously been made of the Com-Pak rectifier notable for its high efficiency and small space occupied. The first equipment embodying eight C7 Type Com-Pak rectifiers has been in trial service in the form of an under-floor mounted unit for British Railways (fig. 10) this equipment being the first of 71 units for multiple-unit stock. These rectifiers have already shown their ability to meet the arduous service requirements of railway operation.

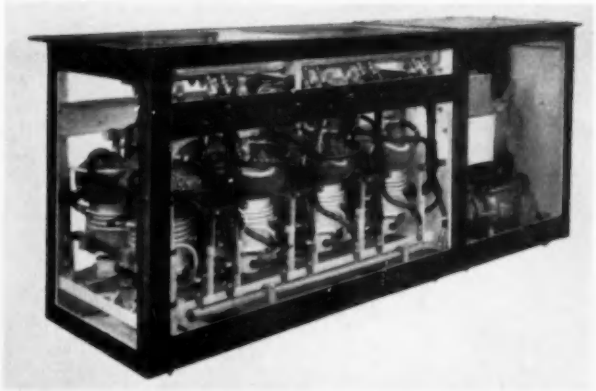


Fig. 10.—Com-Pak rectifier equipment for 25 kV multiple-unit stock.

In addition, the first group of C9 Com-Pak rectifiers

has been delivered and installed in the first of the 25 kV 50 cycle 3 000 h.p. electric locomotives being built for British Railways.

In the semiconductor rectifier field a 100 kW germanium unit with an output of 1 500 A at 67 V has been in continuous service since April, 1959 on electrolytic duty at International Paints Ltd., Newcastle-on-Tyne. The Company is, however, now manufacturing silicon semiconductor power rectifiers, and it is interesting to note that a repeat order obtained from this customer is for a silicon rectifier equipment. Other orders for silicon rectifiers now in hand include an equipment with an output of 2 MW for installation at the Mond Laboratory, Cambridge, and to meet the ever-increasing demand extensive new air-conditioned manufacturing and test plant has been installed (fig. 11).

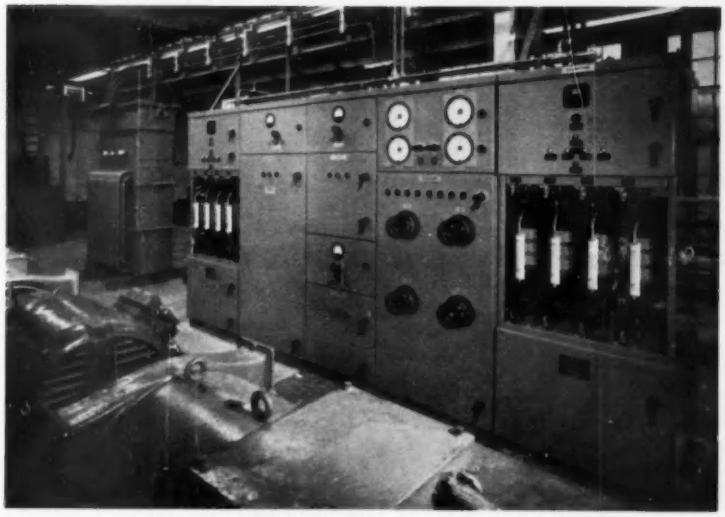


Fig. 11.—Test plant for semiconductor power rectifiers.

INDUSTRIAL ELECTRIFICATION.

During the year important modernization schemes have been successfully completed at the Shotton Steelworks of John Summers Ltd., and the Ebbw Vale Steelworks of Richard Thomas & Baldwins Ltd. An interesting feature of the Shotton scheme is the installation of automatic screwdown control equipment actuated by a positional servo-mechanism. At Ebbw Vale, in addition to the re-motoring of the hot strip mill, which is described elsewhere in this issue, the 4-stand cold mill has been repowered and a new high-speed electrolytic tinning line has recently been ordered.

Plant and control gear for a 16 in. resistance-weld tube mill for Stewarts & Lloyds Ltd., is now under construction. This mill is to be erected at Shotton, and will be the largest tube mill in Great Britain.

Considerable progress has been made on the £4 million contract for the ISCON steelworks at Durgapur. The motors and switchgear for the earlier stages have now been shipped and it is expected that the plant and control gear for the merchant mill, which will be the last section of the rolling mill to be commissioned, will be shipped in the summer of 1960.

Two interesting orders have been received for control equipment for electric furnaces. The first of these will be installed at the B.I.S.R.A. experimental laboratories in Sheffield early in 1960, and is designed to provide line voltage flicker compensation when the 500 kVA arc furnace is in use. The control circuit embodies an 11 kV saturable reactor operating in conjunction with a grid-controlled rectifier. Similar control systems are contemplated for much larger arc furnaces rated at 60-100 MVA. The second order relates to a 1 500 kVA hydrogen-filled processing furnace for annealing stainless-steel tubes used in atomic reactors. In this furnace, which will be installed at the Oldbury Works of Tube Investments Ltd., a magnetic amplifier chain operating in conjunction with a saturable reactor is used to provide temperature control of a high order of accuracy. An installation of somewhat unusual interest has been completed and commissioned for "Pravda", Moscow. Witton-James Ltd., supplied to this office in 1933 a total of 21-reelstands and 14-125 h.p. variable speed a.c. commutator motor driving equipments for

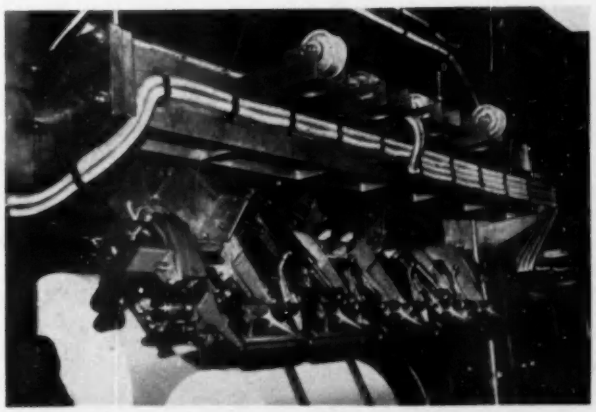
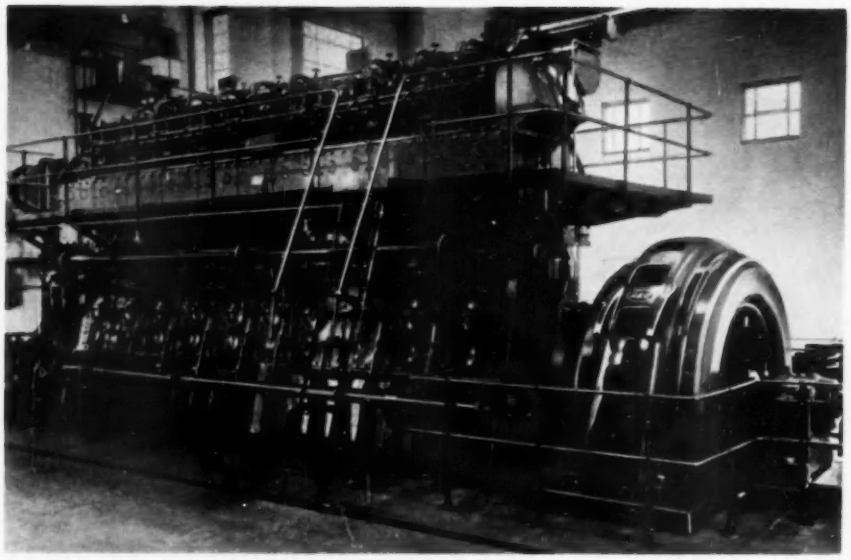


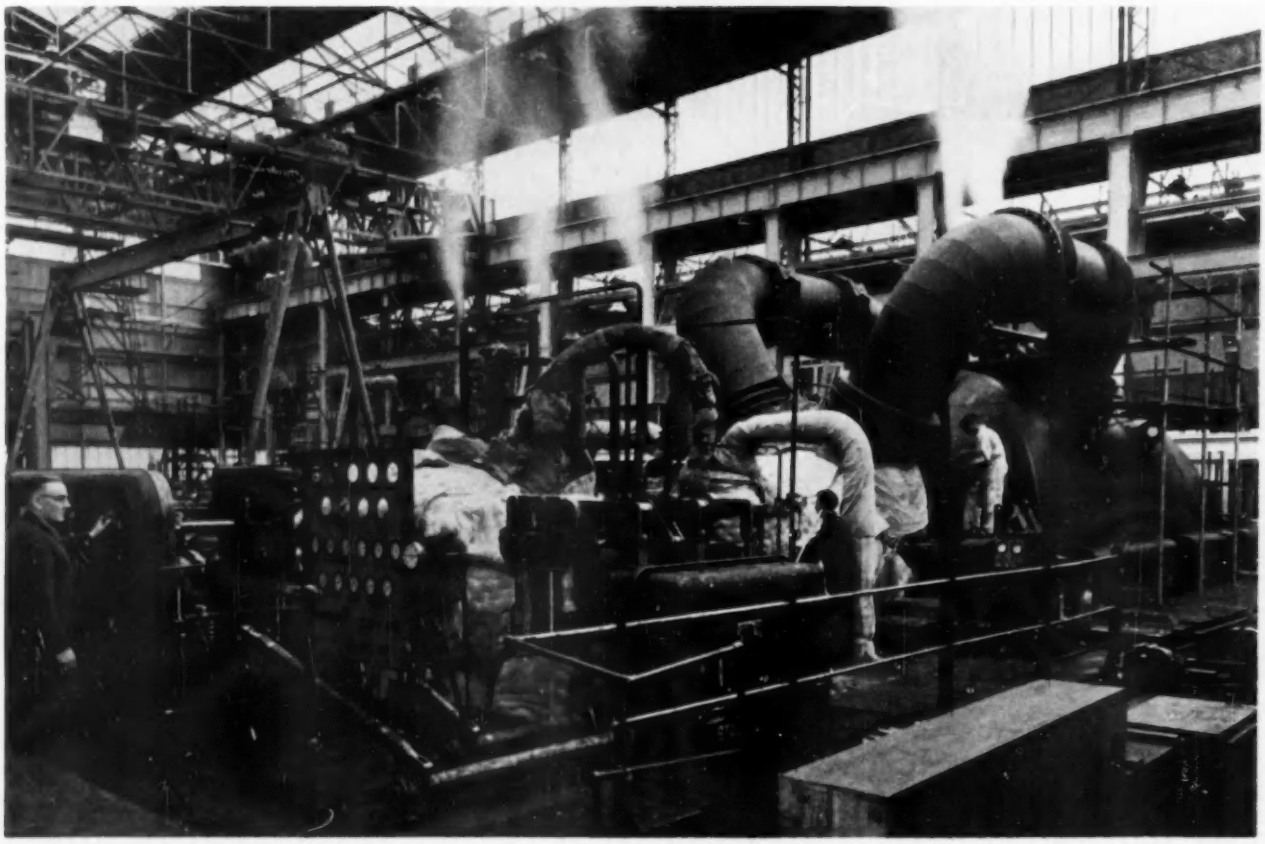
Fig. 12.—Electro-tab Autopaster installed for "Pravda", at Moscow.

Heavy Engineering



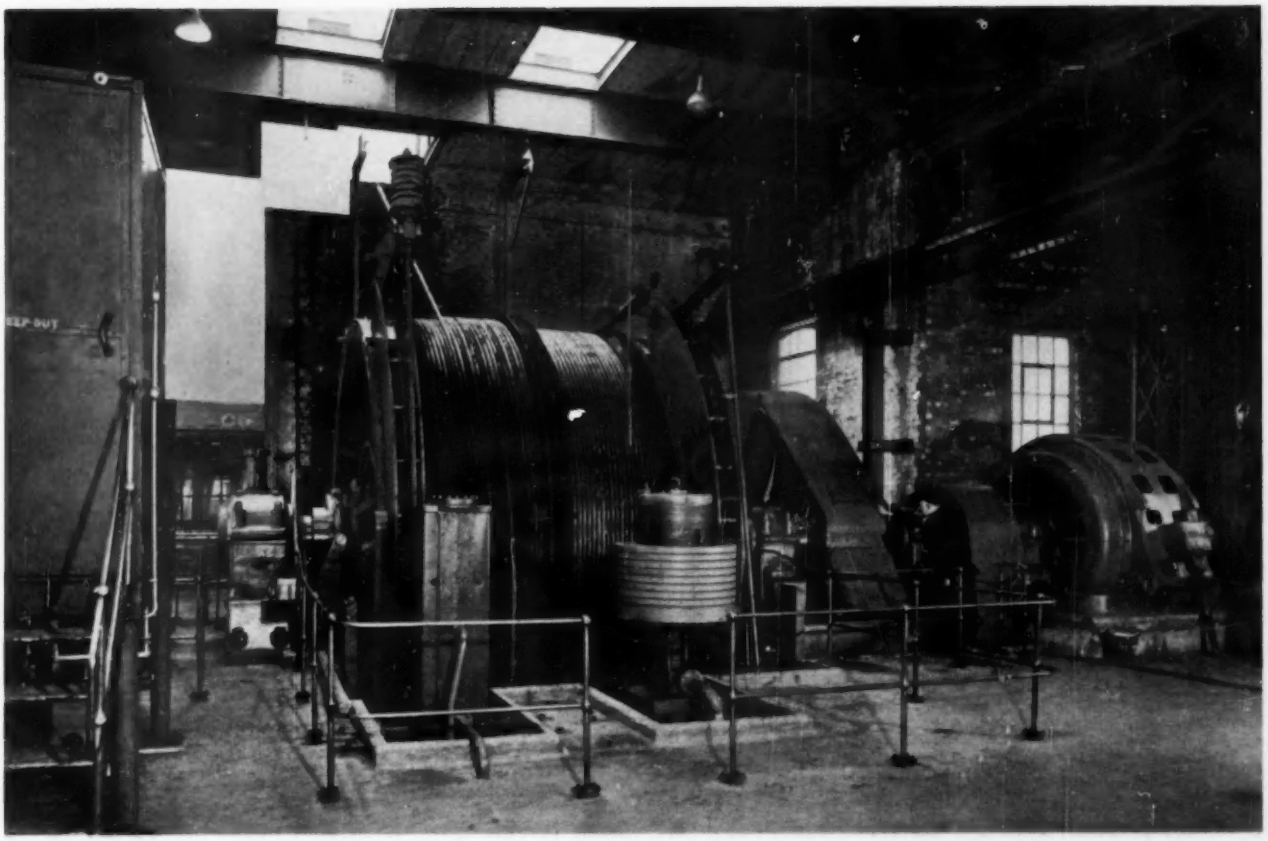
1450 kW diesel-driven alternator in the power station of the Macao Electric Lighting Company on the Kwantung coast.

The second 120 MW steam turbine for the Northfleet Generating Station of the C.E.G.B. undergoing steaming trials at the works. The first set has recently been commissioned.



The wing tripper of a 600 ton/h ore blending plant at the Stanton Ironworks Company Ltd.

2 000 h.p. double-drum a.c. winder at the Littleton Colliery of the National Coal Board.



feeding the paper to and driving a 21-unit high-speed newspaper press.

This original equipment is still on regular daily production and is in such good condition as to warrant the addition of Autopasters to the reelstands to give continuous feed of the paper at the full production speed of the press. At the same time, it was also decided that the modernizing of the web tensioning systems in conjunction with the fitting of the Autopasters was also fully justified.

A contract for twelve sets of these equipments was duly negotiated. This, in line with Soviet custom, was in very precise and elaborate terms. The complete contract was duly executed strictly in accordance with the full provisions of the contract by the due date, and to the entire satisfaction of the "Pravda" engineers. Eight further equipments are now on order, and when these are delivered the complete Witton-James installation at "Pravda", will be equipped with Autopasters and the latest pneumatic web tensioning equipment.

Power Distribution

SWITCHGEAR.

In the sphere of power distribution a dominant feature has been the continued demand for airbreak switchgear for 3·3 kV service. Orders for switchboards of this type rated at 250 MVA breaking capacity are in hand for Tallawara and Wallerawang, Australia, and similar equipment rated at 150 MVA is being built for Mount Isa Mines. Plug-in distribution equipment in the form of motor control centres and power distribution centres for service at medium voltages continues in popular demand, the largest individual customer for this class of switchgear being the ISCON Steelworks at Durgapur, India.

Hydraulically-operated oil circuit breakers for 33 kV service have been developed and are now in production. These breakers are intended as an alternative to spring-operated units in situations where the expense of the storage battery associated with solenoid operation is not justified.

A new design of 11 kV oil switch-fuses has been developed, which includes extensible and non-extensible types in which the fuses are air-insulated. Production of the new range will commence early in 1960.

Of topical interest are the four oil circuit breakers for the Ffestiniog Pumped Storage Scheme in North Wales. These circuit breakers are of the metalclad type and are rated at 3 000 A, 1 500 MVA at 16 kV; they will control the 75 MW machines which operate alternately as generators and motors in accordance with the demand on the national grid system.

Of exceptional interest among the contracts for control equipment is that for capacitor charging units. These are to be installed at Harwell, and will be used in experiments of the Zeta type involving controlled thermonuclear reactions. The units charge capacitor banks to direct voltages ranging from 10 kV to 100 kV; the charging current is controlled by a 3-phase saturable reactor and is cut off by a circuit sensitive to capacitor voltage.

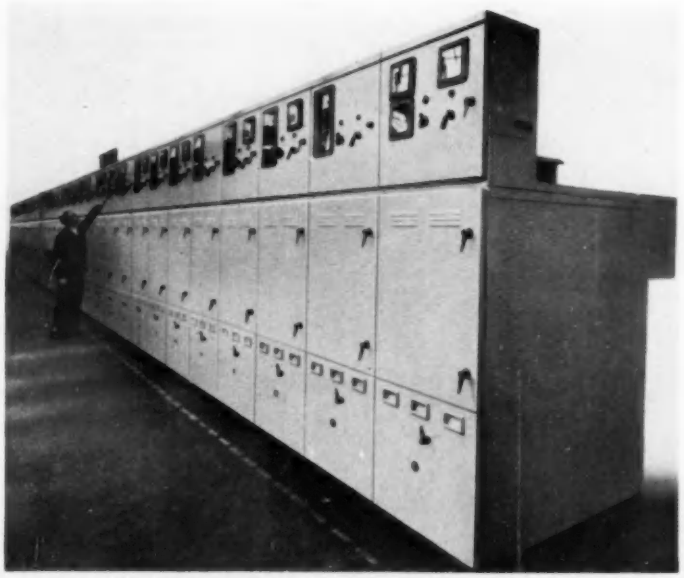


Fig. 1.—3·3 kV 250 MVA airbreak switchboard for Durgapur-Damodar Valley Corporation, India.

An entirely new range of medium voltage a.c. switch-fuses has now been introduced. The equipment is known as the "Hidutac" range, and the design represents a complete breakaway from previous conceptions of small switchgear. Major advances include high current-breaking capacity, high fault-current protection, greatly reduced size and unlimited full-load switching.

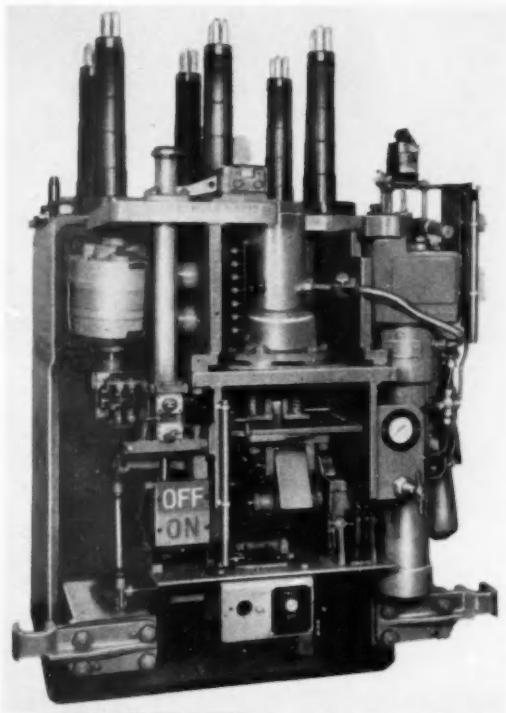


Fig. 2.—33 kV hydraulically operated oil circuit breaker.

TRANSFORMERS.

Development work has continued on very high-voltage transformers and during the year a large 3-phase experimental transformer was successfully tested at an impulse voltage of 1 750 000 V, which corresponds to a service voltage of well over 380 kV. In an effort to establish the design safety margins, the voltage was increased to a level far in excess of the normal flashover voltage of the bushings. This was achieved by enclosing the bushing under test in an envelope containing an electro-negative gas (fig. 3).

The windings of the transformer were auto-connected because the investigation was primarily concerned with the special technical problems arising on auto-transformers. The ratio was 2 : 1 and the size of the transformer tested corresponds to about 240 MVA. Also in the illustration can be seen the controlled chopping device now in general use during impulse testing. This enables the " time to chop " for successive chopped wave tests to be repeatable to within one-tenth of a micro-second.

CABLES.

The field of application of plastic materials as insulants of electric cables for use in the transmission of both power and telecommunication continues to expand. Polythene is extensively used for communications cables, but for low voltage mains distribution cables, increasing use is being made of polyvinyl-chloride (P.V.C.). In general, as opposed to conventional types of paper-insulated cables, P.V.C. insulated

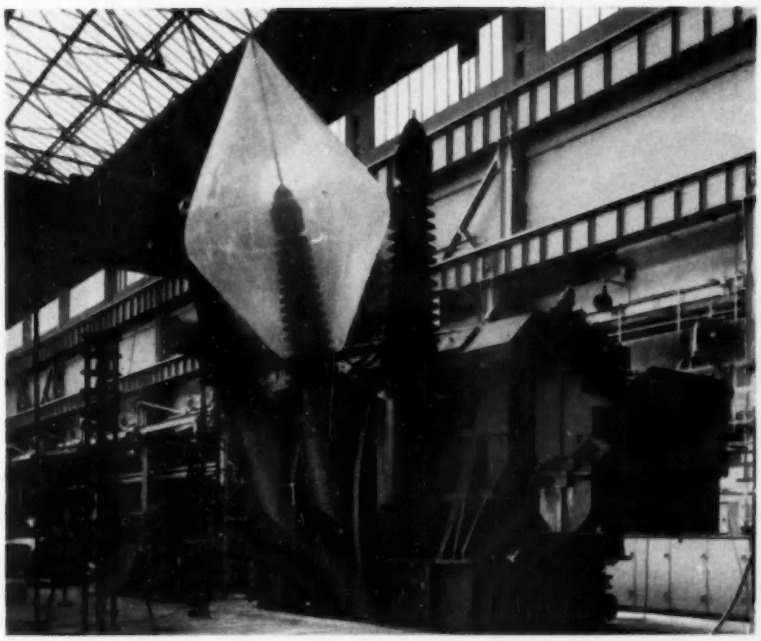


Fig. 3.—Large experimental transformer undergoing impulse test.

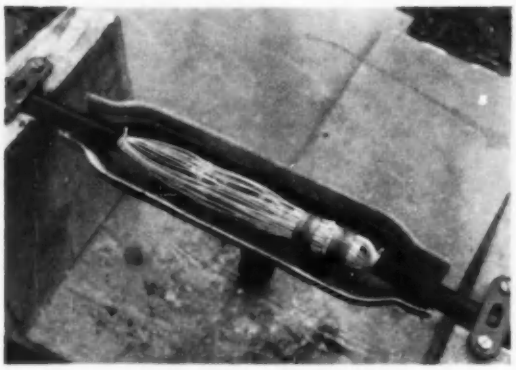


Fig. 4.—P.V.C. cable joint prior to casting.

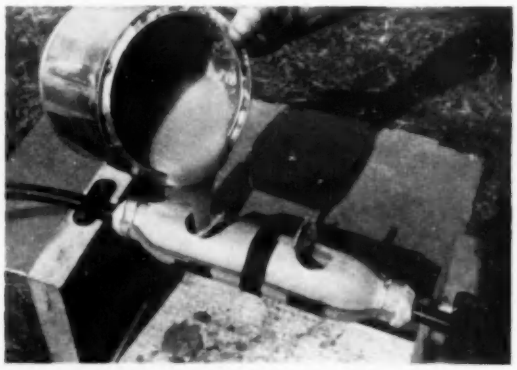


Fig. 5.—Pouring resin into enclosed joint.

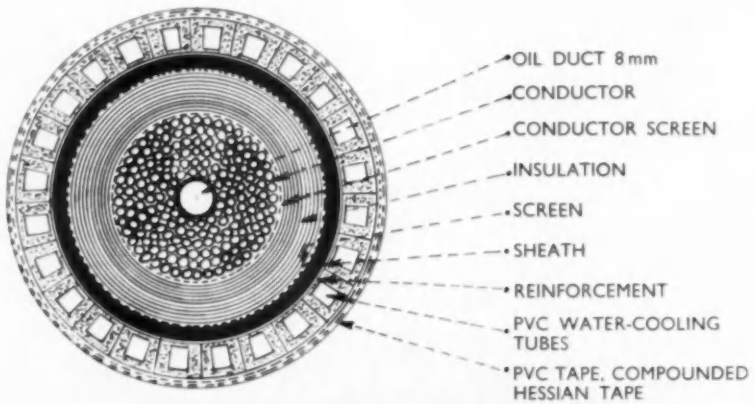


Fig. 6.—Cross-section of 132 kV oil-filled water-cooled cable.

Fig. 7.—Outdoor termination of 132 kV oil-filled water-cooled cable.

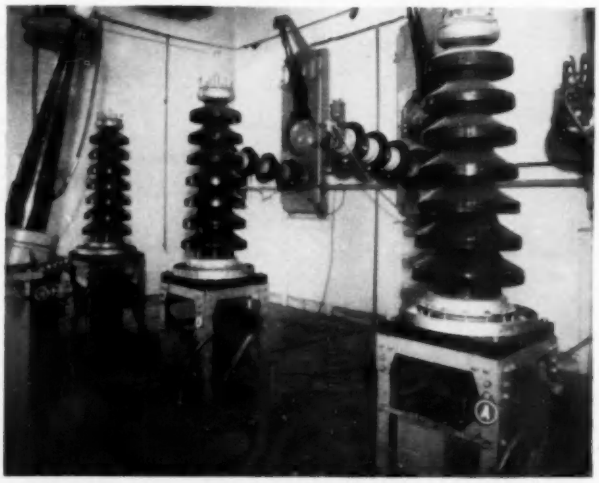


Fig. 8.—Switch-house termination of 132 kV oil-filled water-cooled cable.

and sheathed cables may be installed in the ground without the necessity of providing metallic sheaths.

An interesting and simple joint has been developed for the low voltage type of P.V.C. insulated power cable (figs. 4 and 5). Briefly, the conductors at the joint are insulated with P.V.C. tape coated with a P.V.C. paste, and the electrical continuity of the armouring wires secured by simple mechanical bonds. The insulated joint is embedded in polyester resin cast in situ in a paper mould. The resin, upon setting, produces sufficient heat to cure the P.V.C. paste-coated insulation, and at the same time provides a tough outer protection. The time saved in making this type of joint enhances the economic advantages in the usage of plastic insulated cables, particularly where a large number of branch services are required. Examples of this are street-lighting and housing estates where their employment is being particularly exploited.

The heat losses in power cables govern their maximum loading for a given conductor cross-section. The economic advantage to be gained by controlled dissipation of this heat has prompted the development by Pirelli-General of a unique system of water cooling, and a prototype 132 kV oil-filled cable installation embodying a water-cooling system has recently been completed at Uskmouth Generating Station. Around the metal sheaths of each core a number of small-bore plastic tubes of segmental cross-section are laid-up to form a plastic enclosure containing cooling ducts within its cross-section (fig. 6). At the cable ends the ducts are terminated in specially designed manifolds constructed of synthetic resin. Cooling water supplied at one end of the route passes through the ducts surrounding the cable and is returned to the feed point, dissipating heat during its passage through the return pipe extraneous to the cable system. The water is then available for recirculation. In this manner the cable load-carrying capacity is considerably increased, permitting continuous loads twice as great without danger of overheating and thus providing a valuable overall economy.

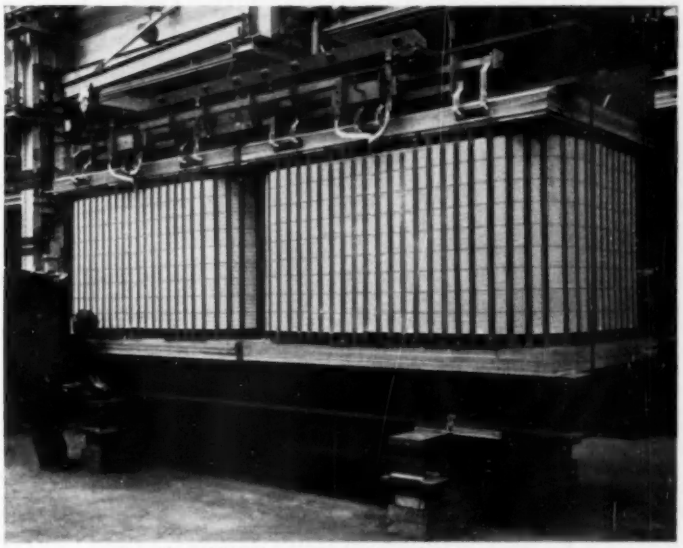


Fig. 10.—100 MVA transductor for turbo-alternator tests.

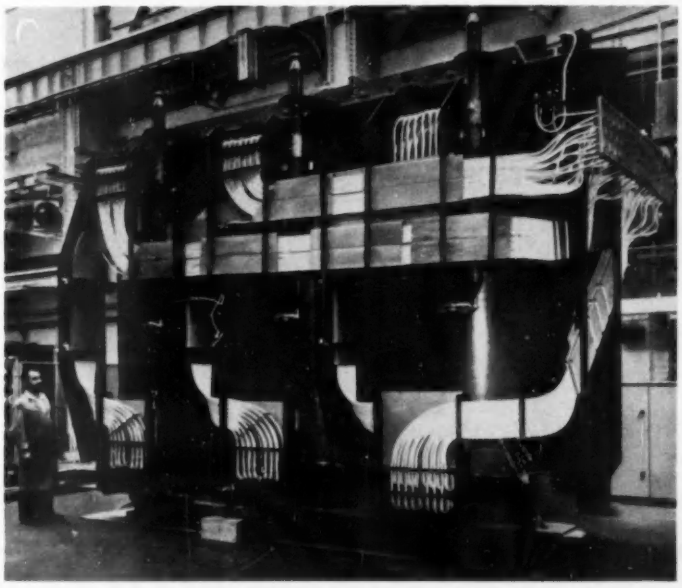
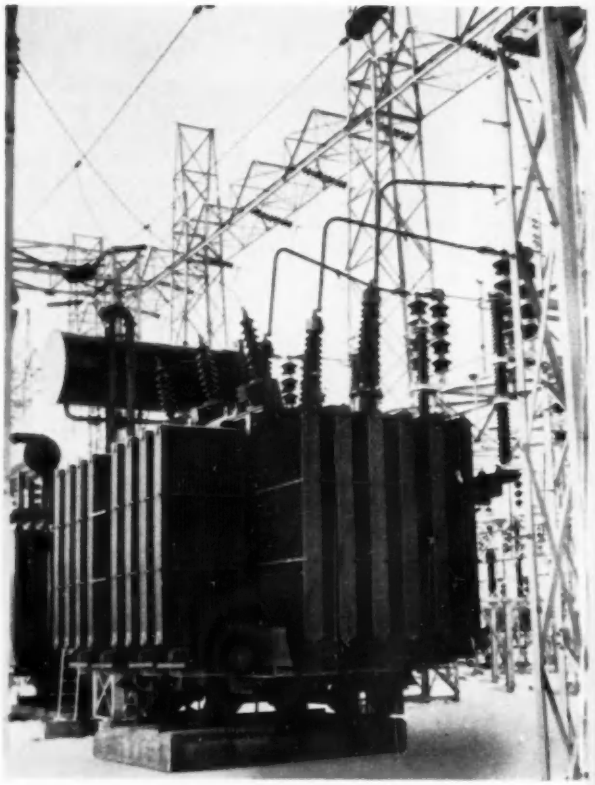


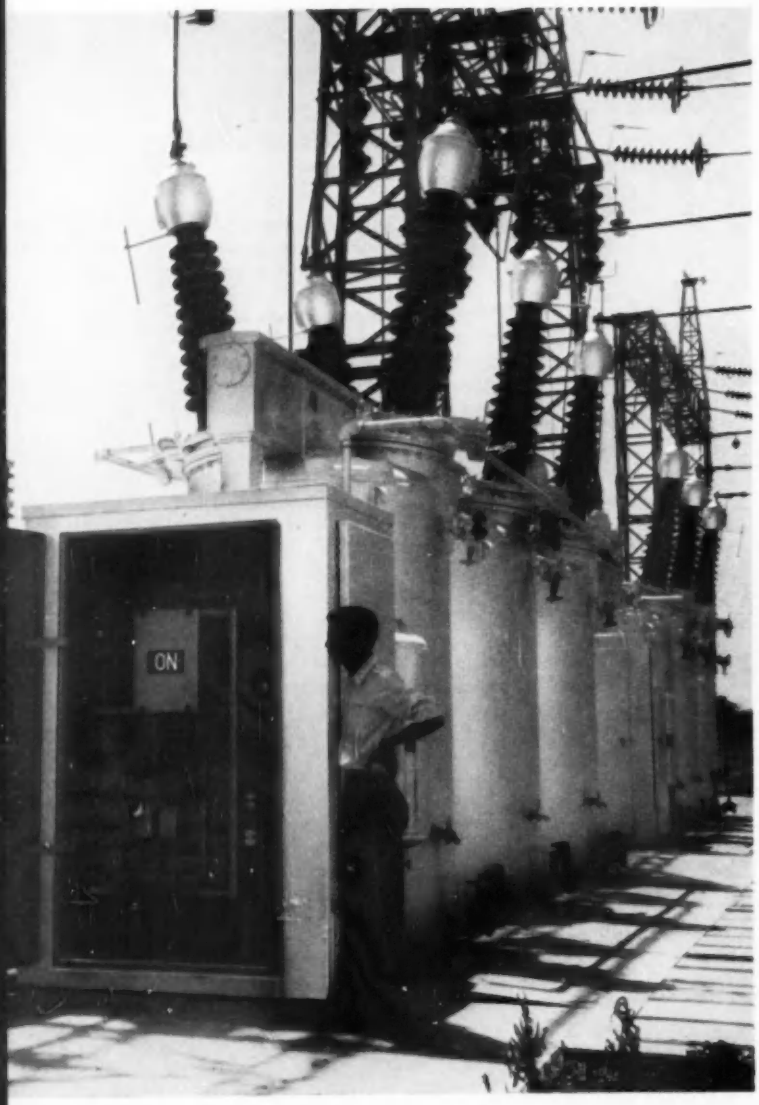
Fig. 9.—144 MVA transformer for Uskmouth "B" Power Station.

Power Distribution

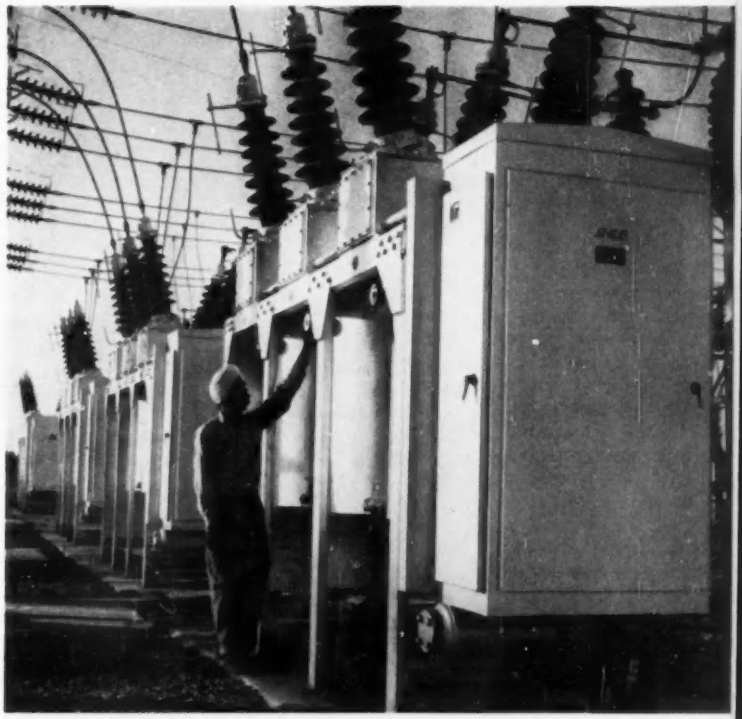
TRANSFORMERS AND SWITCHGEAR



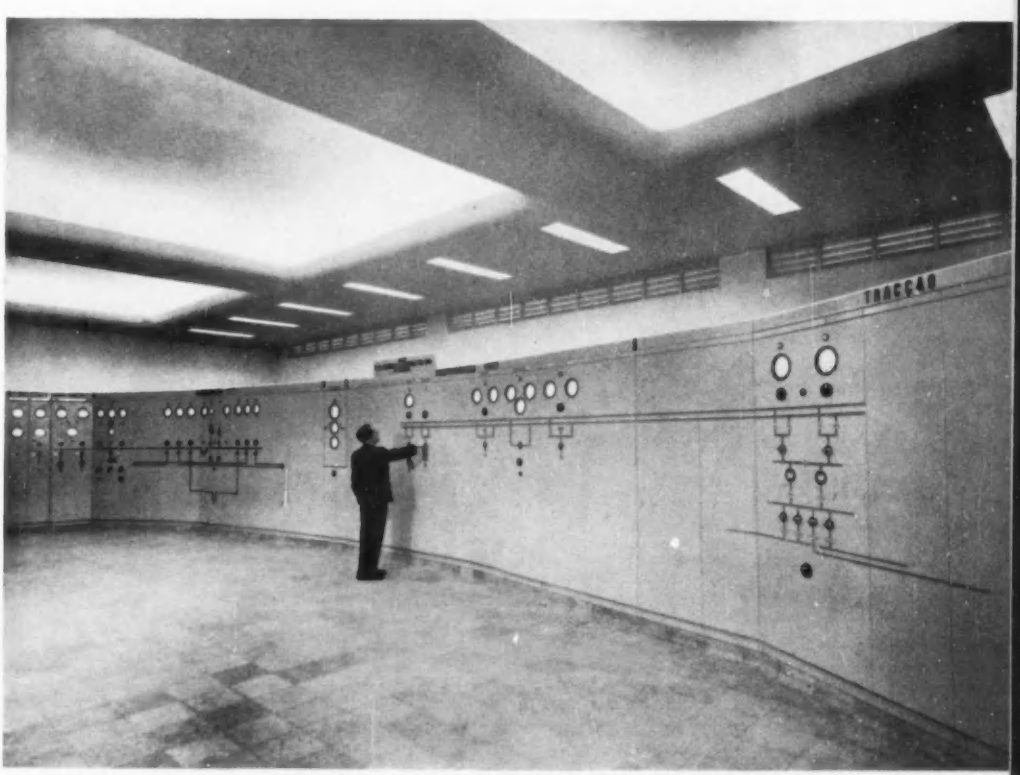
30/40 MVA 138/72 kV auto-transformer at Boundary Dam Generating Station, near Estevan, Canada.



132 kV 1 500 MVA outdoor oil circuit breakers at the Roorkee Outdoor Substation of the Ganges Canal Hydro-electric scheme.



66 kV 500 MVA oil circuit breakers at the Roorkee Outdoor Substation, India.



The main control board for Lisbon's new underground railway.

Transport

TRACTION.

During the year the resources of the Traction Division have been largely devoted to the production of equipments for the modernization of British Railways. The first motor coach for the 25 kV a.c. electrification scheme is on trial on the Colchester-Clacton route, and it is expected that a total of seventy-one of these equipments will be in service by the autumn of 1960.

Over 2 400 traction motors are in hand for the rolling stock on the Piccadilly, Metropolitan and Central Lines of the London Transport Executive and first deliveries have now been effected. Orders for some 1 500 sets of heater couplers for British Railways' with a system of continuous speed control as distinct from the stepped system fitted to earlier locomotives of the same type.

Fig. 1.—1 000 h.p. type 2 diesel-electric locomotive in service on the Eastern Region of British Railways.

The first of ten G.E.C./N.B.L. 25 kV locomotives is now assembled, and will undergo trials on the Glasgow suburban lines prior to entering service in the Manchester area of the London Midland Region early in 1960.

The electrical equipment for the five high-speed diesel-electric de luxe pullman trains for service on the London, Midland and Western Regions of British Railways has been completed. The twenty type 2 diesel-electric locomotives now in production for the Scottish Region of British Railways are to be equipped electrically hauled trains have been received, and it is hoped that the G.E.C. design will be standardized for this purpose.

The three 4-car 1 500 V d.c. electric trains for the Estoril Railway, Portugal are now in commission. Built to the Budd design, these new trains are being used to provide an improved limited-stop service between Lisbon and Cascais at maximum speeds approaching 60 miles/h.

For Lisbon's new underground railway, the Metropolitana de Lisboa, which was commissioned in

December, 1959, the G.E.C. has supplied high-voltage switchgear, transformers, rectifiers, ventilating and pumping equipment and cabling, as well as an 850 kVA diesel-alternator for emergency supplies. The incoming 10 kV a.c. supply is converted to 750 V d.c. by two twin-cylinder mercury arc rectifier equipments each rated at 1 500 kW. Tunnel ventilation is provided by 48 in. 2-stage Aerofoil fans.

Fig. 3.—Relay interlocking control panel at Temple Mills (Stratford) on the Eastern Region.

RAILWAY SIGNALLING.

The Siemens and General Electric Railway Signal Co. Ltd. were the first to receive a contract for signalling on lines to be worked on the high-voltage a.c. system. The section of British Railways from Colchester to Clacton and Walton was used as a proving ground for the 25 kV electric trains. The contract covered some twenty-five route-miles from Colchester to the coast via Thorpe-le-Soken at which point the lines divide to serve Clacton-on-Sea in one direction and Walton-on-the-Naze in the other, as well as the Hythe-St. Botolphs branch line and the line from Wivenhoe to Brightlingsea as far as the outer home signal.

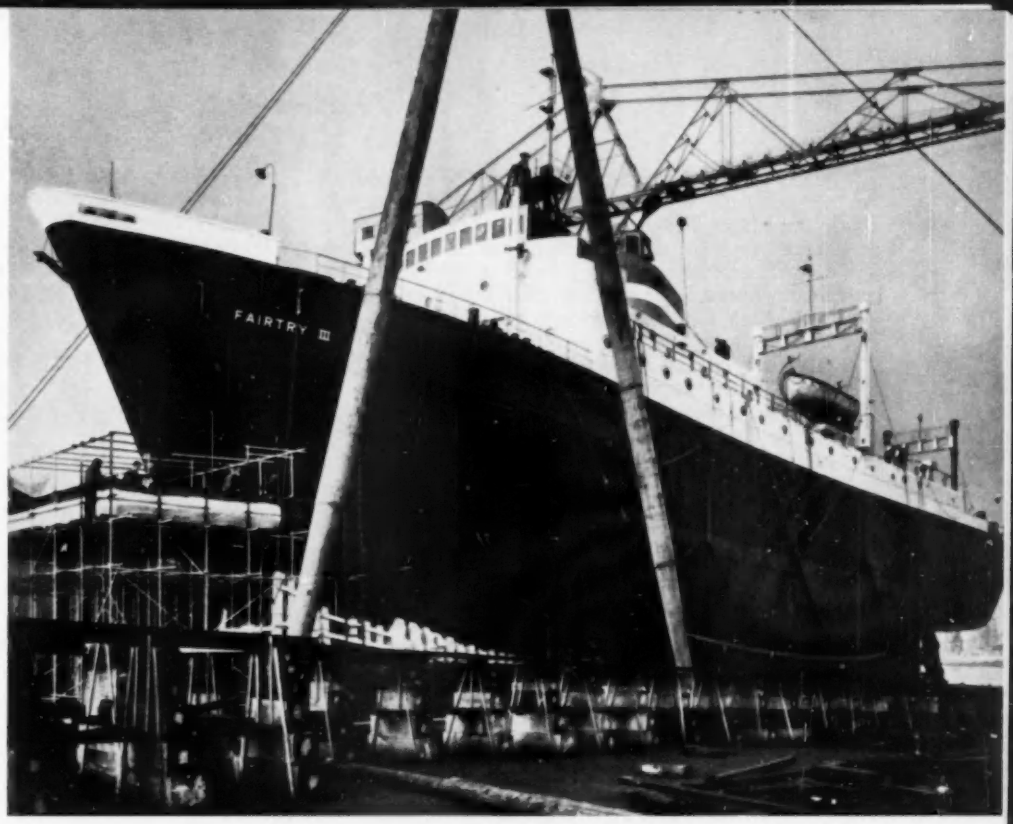
The installation, which opened in February, 1959, was designed so that all equipment would have adequate immunity from the inductive or other

Fig. 2.—Searchlight signal and multi-lamp route indicator at Clacton-on-Sea.

Fig. 4.—Automatic signalling at the approach to Dunswart, South African Railways.

Transport

Transportable motor-alternator set servicing a Boeing 707 jet aircraft of Qantas Empire Airways.



Fish factory trawler "Fairtry III", recently launched by Wm. Simons and Co. Ltd., will be equipped with G.E.C. multiple-unit diesel-electric propulsion equipment identical with that of her sister ship, "Fairtry II".

1 500 volt d.c. electric train in service on the Estoril Railway, Portugal.

effects of the 50 c/s traction current. To this end, all relays are d.c. types and, for other equipment lacking in impedance, chokes are provided. Track circuits are limited to 500 yards in length and no line circuits exceed five miles. Searchlight signals and track circuits operating on d.c. were installed throughout.

Two other contracts from British Railways recently completed by S.G.E. include a route relay interlocking installation forming part of the southern approaches to the new Temple Mills mechanized marshalling yard near Stratford on the Eastern Region, and the resignalling of Huddersfield Station and its approaches on the North Eastern Region.

On the Southern Region S.G.E. have signalled twenty-eight miles of double track from Farningham Road to Sittingbourne and 7·5 miles of single track from Sittingbourne to Sheerness. The line to Sheerness is remotely controlled from Sittingbourne. Train describers were installed throughout from Brixton to Ramsgate. On South African Railways, S.G.E. have installed automatic signalling from Dunswart to Alliance using searchlight signals and d.c. point machines. Daveyton Station, 1·5 miles beyond Alliance, is remotely controlled from Alliance. Colour light signalling has also been carried out on the new lines from Germiston to Angus.

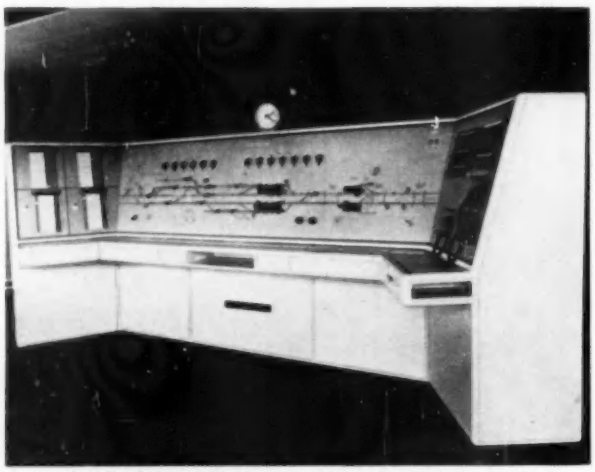


Fig. 5.—Relay interlocking control panel at Rochester on the Southern Region.

MARINE ELECTRIFICATION.

In the sphere of marine electrification the increasing popularity of alternating current has given rise to a series of orders for generating plant, "Accurex" automatic voltage regulators and switchboards for ships, auxiliary supplies. The more important of these include five vessels for the Lowland Tanker Co. Ltd., the new liner "Canberra" together with three tankers, for the P. & O. Steamship Co., and the ore carrier "William Grey" for Houlder Brothers & Co. Ltd.

Propulsion schemes incorporating multiple-unit diesel-electric drives continue to find favour in applications where economy in operation, manoeuvrability and versatility of power supplies are important considerations, a number of interesting vessels incorporating this form of propulsion are under construction. Following the successful commissioning of the fish factory trawler "Fairtry II" in April, 1959, her sister ship "Fairtry III" entered service in February, 1960.

Fig. 6.—60 kVA diesel-powered alternator for servicing aircraft.

These vessels combine the functions of trawler and fish processing plant and in consequence require more elaborate electrical installations than conventional trawlers. Similar propulsion units are under construction for a 2 220 ton dredger and a 60 ton floating crane for the Mersey Docks & Harbour Board and for two chain ferries linking Tor Point and Devonport on the A38 route to Cornwall.

AIRCRAFT EQUIPMENT.

For servicing, testing, overhaul and repair of Boeing 707 jet aircraft, the Company is supplying to the order of Qantas Empire Airways Limited a number of motor-alternator sets of several styles, fixed, transportable, and mobile. The equipment consists of an a.c. motor flexibly coupled to a 400 c/s 3-phase alternator complete with an "Accurex" automatic voltage regulator, control gear, instruments and relays, all mounted upon a combination bedplate.

The fixed indoor sets are arranged in "open" style, the transportable and mobile sets being fitted with sheet steel weatherproof canopies with provision for adequate ventilation.

Similar ground power units for aircraft servicing,

incorporating G.E.C. machines and "Accurex" regulators are being built by Auto-Diesels Ltd. The diesel-powered version shown in fig. 6 has an output of 60 kVA 3-phase 400 c/s ; special types are also being produced for service on naval aircraft carriers.

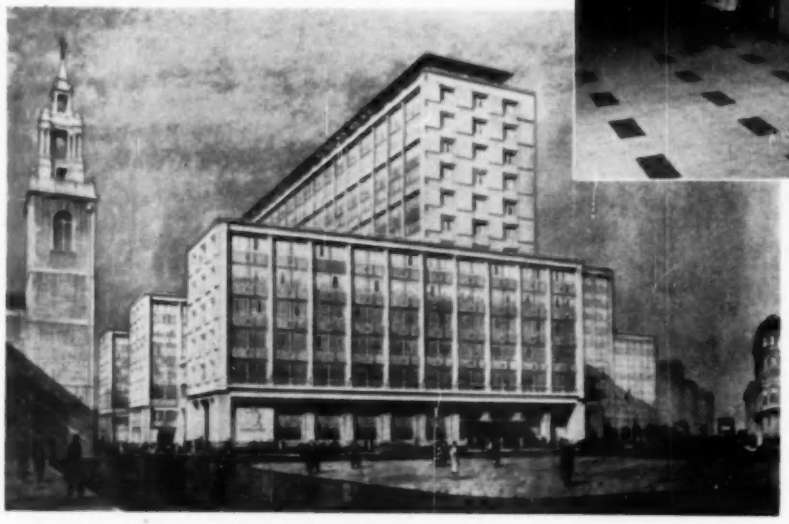
A new 1·5 kW mobile landmark beacon for use on aerodromes has recently been designed to meet the requirements of the Ministry of Supply. Powered by a 908 c.c. petrol engine, the beacon provides a flashing signal in morse characters from a lantern housing four 300 W hot-cathode neon tubes. The unit is mounted on a two-wheel chassis, and the output of the alternator is regulated by means of a Boucherot stabilizer. So far, forty-two of the new beacons have been delivered, and some are now undergoing operational tropical tests overseas.

An inverter to provide an a.c. supply for instruments and special equipment in aircraft fitted with 28 V d.c. power systems is now in production. It has a 3-phase output of 750 watts at 115 V, 400 c/s, and will give satisfactory operation over a wide range of ambient temperatures and altitudes. The unit is suppressed to prevent radio interference and has a total weight of approximately 30 lb.

Airborne electrical equipment is now being supplied to 104 of the world's leading airlines and air transport organizations, and in the field of airborne catering equipment the G.E.C. now ranks as the world's leading supplier. This position has been gained only in the face of fierce competition from manufacturers in the U.S.A.

Fig. 7.—The galley of a B.O.A.C. Britannia fitted with G.E.C. ovens, urns and heated food containers

Electric Lifts



Bucklersbury House, London, is equipped with a comprehensive system of passenger and goods lifts supplied by the Express Lift Company. The illustration on the right shows the entrances to a group of lifts equipped with express traffic control and an automatic traffic analyser, and operating at a speed of 700 ft min.

Part of the extensive lift installation at B.P. House, London.

Lamps and Lighting

LAMPS.

Osram lamps have again obtained the largest share of the lamp market in the United Kingdom, and continue to make an important contribution to the Company's exports. A notable feature has been the increasing use of the more efficient coiled-coil lamp in the household range of G.L.S. lamps. Recent technical advances have played a significant part in securing the substantial price reductions in these lamps which have been made during the year. Important among these advances is a novel conveyor system, at the Wembley Lamp Factory, which delivers trays of bulbs of the appropriate type and at the appropriate speed from the store on the ground floor to the various lamp-making groups on the second floor. The bulbs are taken automatically from the trays and washed internally as they pass to the lamp assembly machinery.

Fig. 1.—The Osram 7 in. sealed-beam headlight.

In the realm of special purpose lamps, a new company—British Sealed Beams Ltd.—has been formed in partnership with A.E.I. Lamp and Lighting Co. Ltd. and Joseph Lucas (Industries) Ltd., to produce glass sealed-beam headlights for the motor industry. The high degree of mechanization in manufacture ensures that every headlamp gives the shape of beam intended by the designer, with a life and beam intensity maintenance much superior to existing headlamp systems.

Accurately pressed hard glass components, sealed together at their edges, form an envelope to house two exactly positioned filaments for the main and passing beams. The rear pressing is internally metallized to provide a parabaloid reflector and the front pressing is moulded with a carefully designed pattern of prisms and lenses giving the most advantageous light distribution in both beams. Glass lugs on the periphery and front face of the lamp facilitate its installation and alignment in the vehicle. A 7 in. headlamp will be the first to go into production (figs. 1 and 2) and will be followed by a smaller version for four-headlamp systems and a spotlight.

Other special types of incandescent filament lamp introduced during the year include two new projector lamps with valve-type pressed glass bases (fig. 3). Decorative sets using sub-miniature lamps have been made available in strings of twenty 12 volt lamps as well as forty 6 volt lamps. The special capping cement used becomes conducting and shorts the leads when a lamp fails, thus ensuring continued operation of the string.

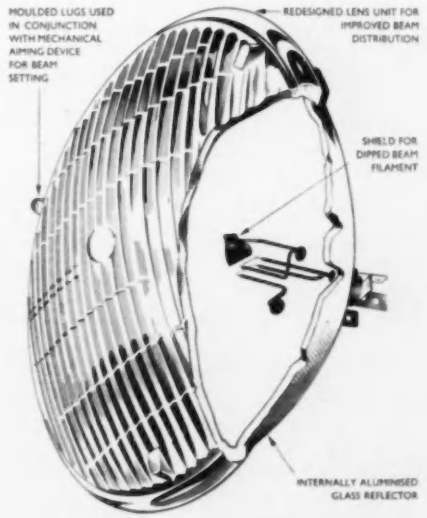

MOULDED LUGS USED IN CONJUNCTION WITH MECHANICAL AIMING DEVICE FOR BEAM SETTING
REDESIGNED LENS UNIT FOR IMPROVED BEAM DISTRIBUTION
SHIELD FOR DIPPED BEAM FILAMENT
INTERNALLY ALUMINISED GLASS REFLECTOR

Fig. 2.—Construction of sealed-beam headlight.

Fig. 3.—New pin-base projector lamp.

Quartz tubular infra-red heaters are being increasingly used in many industrial and scientific applications. A 2 kW heater has been added to the range and all types are no longer restricted to horizontal operation. A particularly interesting application of these tubular heaters is their use for the heat-stressing of aerodynamic structures at the Royal Aircraft Establishment, Farnborough.

Much attention has been given to securing economy in the manufacture of fluorescent tubes without sacrifice of the exceptionally high efficiency and life performance obtained in recent years. Simplification and mechanization in the manufacture of phosphors, and in the process of particle size classification, have contributed to this. Another aspect of the work is the elimination of inflammable solvents by the use of water-soluble binders, in the phosphor coating process, resulting in a tube of improved appearance.

Developments in high-pressure mercury vapour lamps have been concentrated in improvements of techniques and facilities for the production of the range of H.P.M.V. fluorescent lamps which, with their good colour rendering, are gaining popularity for industrial lighting and street lighting in all parts of the world. Their high wattage loading encourages the trend towards higher levels of illumination.

In sodium lamps, the introduction of the efficient and reliable Integral lamp by the Company three years ago and its more recent extension to the Double Integral lamp rated at 280 watts, has stimulated interest throughout the industry in the possibility of further technical improvements based on similar principles. In practice, the Integral lamp has greatly extended the usefulness of the sodium lamp for main highway lighting.

LAMP OPERATING EQUIPMENT.

The Company has maintained its lead in the design and use of transistor equipment to operate fluorescent tubes from d.c. supplies for transport lighting. Both transistor inverters and power packs suitable for operating a range of fluorescent tubes, including all ratings from the 40 W downwards, singly or in groups, are now available. Considerable use of this transistor gear will be made by British Railways and the Pullman Company for railway coach lighting. Experimental installations are being tested by bus and coach operators. Experience has also been gained in this field for aviation lighting and several "Vanguard" aircraft are now flying equipped with transistor-operated fluorescent tubes.

The public demand for aesthetically acceptable lamp columns for street lighting had led to progressively slimmer designs with smaller gear compartments. This has required further reductions in the cross-sections of ballasts for sodium and mercury street lighting lamps. The design of suitable ballasts for this purpose has been made possible by the

Fig. 4.—Great West Road, London, lighted with colour-modified H.P.M.V. lamps.

Fig. 5.—Lantern for Birmingham City Circle Road.

introduction of special thermo-setting fillers of high thermal conductivity.

Cold cathode fluorescent lighting continues to be installed with success in many liners, and complementary with this, instant-start mains voltage fluorescent lighting is also used on many of the new vessels. Some of these are equipped with unusual a.c. supplies and have involved various technical problems which have been overcome. Fluorescent lighting is now being installed successfully in the staterooms, lounges, dining rooms, etc., of various new passenger vessels, including the " Canberra " and " Oriana ".

ILLUMINATING ENGINEERING.

The many specialized branches of lighting all have their own special techniques. While each of these has advanced by experience and experiment in its limited field, much has also been gained by a knowledge of other branches. Street lighting practice, for example, has long been based on the principles mainly evolved and published by the G.E.C. Research Laboratories in the early 1930s, in which high road brightness, to give good silhouette viewing, is produced by the appropriate light distribution from the lantern. Although this is the most commonly used technique in Great Britain, instances have recently occurred where methods more akin to floodlighting are appropriate.

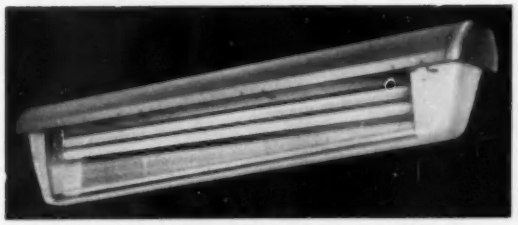


Fig. 6.—Tapered lantern for tubular fluorescent lamps.

The installation on the Great West Road, illustrated in fig. 4, is an example of orthodox technique using the 400 watt colour-corrected mercury lamps in lanterns designed to house the relatively large source in a neat and efficient optikon. For the Birmingham City Circle Road, however, rather less orthodox methods were employed in planning the installation. New and specially designed lanterns, shown in fig. 5, were used (opposite mounted) with a mounting height of 30 ft and a spacing of 100 ft. Each lantern is equipped with three 400 watt colour-corrected mercury lamps to give a high illumination on the road and a high brightness dependent less than usual on " glancing " angles of incidence, so that good visibility is achieved with little glare.

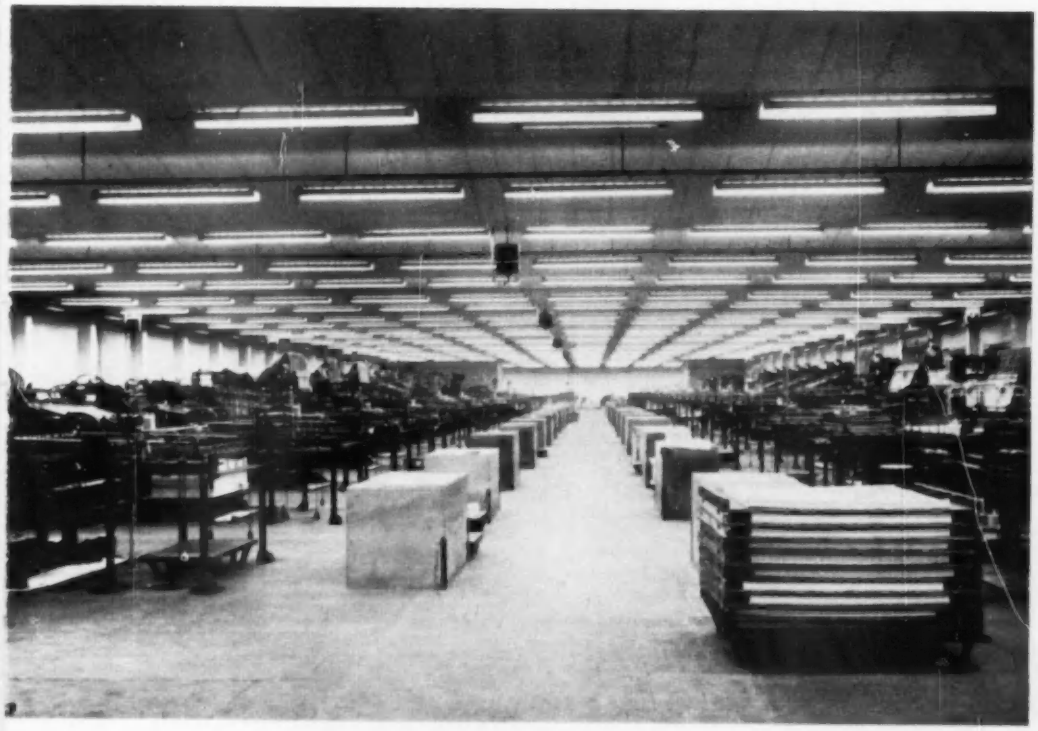
Fig. 7.—Office lighting with new " Comfort in Lighting " fittings at the Ford Motor Co. Ltd., Dagenham.

Some Lighting Installations of the Year

The Council Chamber of the new Guildhall, Portsmouth. The raised centre ceiling is illuminated by 4 ft fluorescent tubes and the curtains and pelmets are lit by concealed architectural lamps.

The Concert Hall at Portsmouth Guildhall. Warm white cold cathode tubing is used to provide the main illumination.

Recessed lighting at Maples furnishing store, Tottenham Court Road, London.



Fluorescent lighting at the Watford works of Odhams Press Ltd.

Lighting Installations

"Designed Appearance" lighting at Liverpool Cathedral.

The Omar Ali Saifuddin Mosque at Brunei, North Borneo.

Kai Tak Airport, Hong Kong.

The Auckland Harbour Bridge, New Zealand.

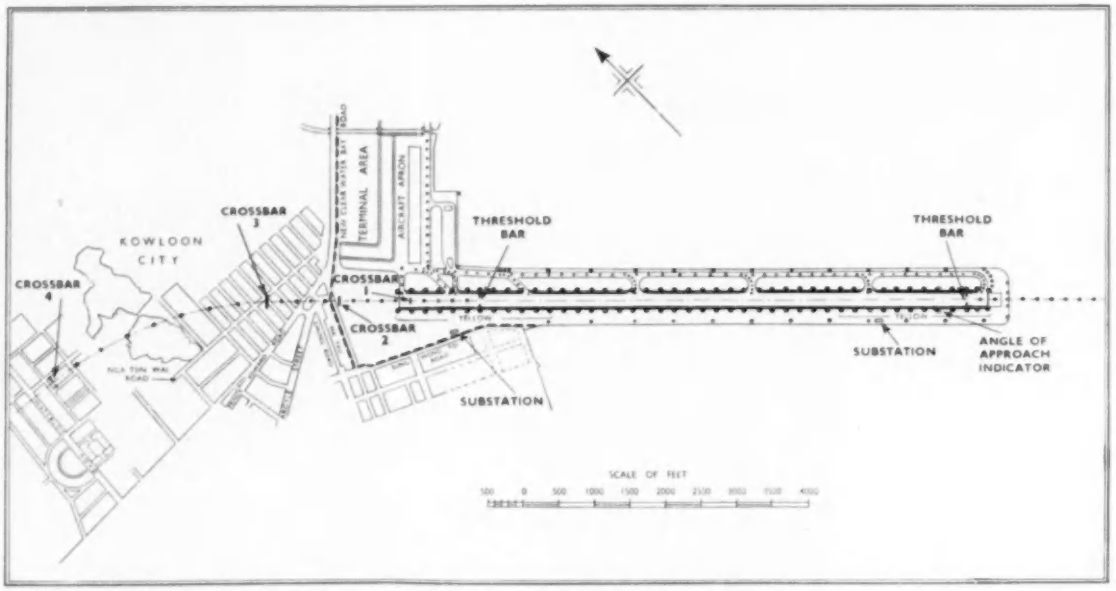


Fig. 8.—Plan of approach and runway lighting of Hong Kong airport.

Although a great many standard designs of street lighting lantern are available it is still necessary to design special types. The use of good street lighting is advancing so rapidly, and the variations in streets in Great Britain and abroad are so great, that new and special designs, one of which is illustrated in fig. 6, are constantly required. These modern lanterns are more efficient and cheaper than their predecessors, and more of them have been installed during the year than ever before.

The need for special designs arises even more often in interior lighting. Installations such as those at the Brunei Mosque (page 34), the Bank of England, and the Bank of London and South America each represent the solution of a particular set of problems, requiring laboratory experiment and the design of special equipment. An approach from basic principles, with an accumulated experience, leads the designer to the best solution for each particular building.

The approach from first principles is always important and the Designed Appearance Technique is proving its value in this way. Since the notable installation at Gloucester Cathedral, many others have been designed by this method. Among them are several which at present exist only on paper and largely in the mind of the architect, for example, Carlisle, Ripon and Edinburgh Cathedrals.

Although the great bulk of lighting is carried out with standard equipment, imagination in design has shown itself in new methods of using this as well as in the development of new equipment, which often raises fresh technical problems. The trend towards

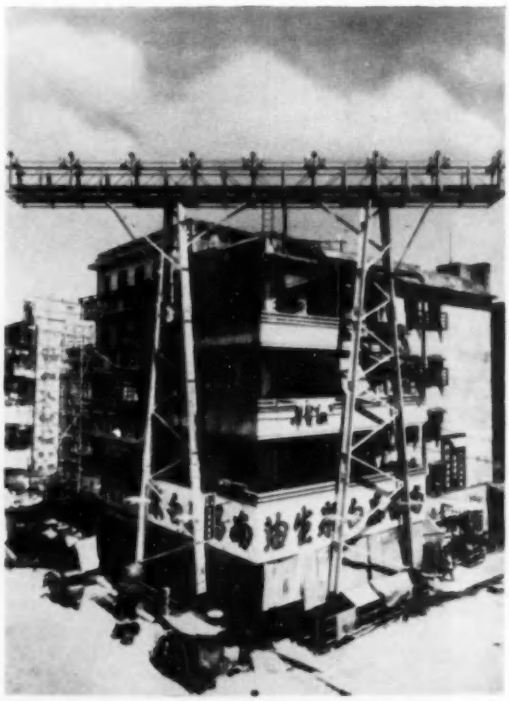


Fig. 9.—Part of a cross-bar of the N.W. approach lighting of Hong Kong airport, sited at a street corner.

the use of small lamps in rather compact equipment has, for example, required new studies of thermal conditions in the fittings.

The limitation of glare has continued to be one of the most important considerations in the design of a lighting installation, and the importance of this becomes greater as the illumination values used tend to become higher. Whereas a value of 10 lumens per square foot would have been considered adequate for ordinary work in an office a few years ago, the development of more efficient light sources has led to the concept of much higher illuminations being both desirable and valuable. These high illuminations need careful planning if the installation is to be pleasant.

The G.E.C. has, therefore, after several years of research and development, introduced a range of "Comfort in Lighting" fittings which are suitable for providing such high levels of illumination. The light distribution is carefully controlled by aluminium reflectors or prismatic refractors in such a way that, not only is the bare lamp screened from view, but the skirt of the fitting has a level of brightness far below the value which could cause glare. In some designs special stepped "Lowglow" louvres are used to achieve a similar effect. Equipment is available for a variety of purposes including use in shops, factories and offices. An example is shown in fig. 7. The efficiency of the equipment is high and it is expected that these and similar designs will have a notable effect on the lighting techniques of the future.

In the field of airport lighting the intricacies often encountered were amply illustrated at Hong Kong's new airport, Kai Tak, which juts out 1½ miles into the sea, and is designed to be fully operational 24 hours a day even for the largest aircraft. Nearby hills and a densely populated city precluded a direct landing approach from one direction. To overcome this a curved line approach system was introduced—the first of its kind in the world (fig. 8). The approach lights were mounted on special structures spanning buildings and streets, fig. 9, and on piles driven into the sea bed. The lighting system is remotely controlled from the aircraft control tower; five steps of brightness are provided for the high intensity lighting used in bad visibility and a low intensity for normal conditions. Kai Tak is now open in all but the very worst conditions. A night view of the airport is shown on page 35.

Telecommunications and Electronic Engineering

Within this Group the Company manufactures a wide range of telecommunication and electronic equipment. The products cover the requirements of the General Post Office telephone service at home, as well as those of overseas telephone administrations, remote control systems, long-distance speech and television transmission systems and designs and manufactures of electronic equipment, both for civilian and defence purposes.

A considerable impetus to advances in telecommunications has been given by developments in semiconductors, printed circuits, automatic methods of assembly and miniature components. The resulting advantages in smaller, less expensive units, with lower power consumption, less maintenance, greater reliability and higher speed of operation, have affected all aspects of telecommunications, but with differing degrees of emphasis.

The trunk-dialling equipment ("GRACE") which was installed at Bristol exchange has been in service for twelve months and is giving very satisfactory performance. It is interesting to note that more than nine out of ten calls which can be dialled direct by the subscriber are in fact initiated in this way, little use being made of the alternative operator service. Identical Group Routing and Charging Equipment is being manufactured for Leicester exchange and for other cities in "non-director" areas to which this equipment is applicable. It will be followed during the coming three years by a development of the system for the larger, "director", areas and the Company is playing its part in the manufacture and installation of the necessary equipment.

In conjunction with the General Post Office and the other principal contractors, considerable development resources are being applied to the completion of a fully electronic telephone exchange. The laboratory model of this is set up and working at the Dollis Hill Research Station of the G.P.O. (fig. 1) as a further step towards the installation of the first public electronic exchange at Highgate Wood. The problems associated with this venture have been thoroughly assessed but their practical solution may take several years. There is a world-wide interest in electronic switching methods and faith in their ultimate success, but the attainment of fully proved systems will inevitably require the exploration of many developments and the abandonment of some of them.

A new range of subscribers' telephone instruments is in production (fig. 2). These have an improved appearance and better performance than existing types and are made in a wider range of colours to suit any décor.

In the field of long-distance communications

Fig. 1.—Experimental G.E.C. electronic telephone exchange equipment at Dollis Hill Research Station of the G.P.O.

numerous schemes have been commissioned in various parts of the world and steady progress has been made in the expansion of overseas markets for this equipment. Successful installations of microwave radio systems at 2 000 Mc/s are being followed by a 6 000 Mc/s broad-band system for conveying television and/or telephone signals. This system, together with the others available at present, will cover every type of requirement, in all kinds of territory, for both light and heavy traffic loading. Tropospheric scatter propagation is entering a new phase of extended field trials with a small capacity, five-channel system operating in the 2 600 Mc/s band.

In the field of control systems and electronics, good strides have been made during the year. The Special Systems Division, which deals with remote control problems of railway electrification, power stations (including atomic stations), etc., has been fully occupied, and the Electronics Division formed to extend and co-ordinate many electronic activities has become effective. Systems have been developed for transmitting, receiving and displaying digital information of all kinds. The systems can be operated over any of the channels of communication mentioned above.

ELECTRONIC ENGINEERING

The success of research and development programmes for the Government is reflected in the continuation of significant commitments for the design and manufacture of complex electronic and radar control systems. Increasing resources are now being devoted to civil aspects of electronics.

The advent of transistors has enabled efficient units to be offered for converting low-voltage direct-current supplies to operate fluorescent tubes (fig. 3). These power units give efficient operation of the tube throughout a long life. A lightweight 12 to 15 watt unit has been accepted for the new Vickers Vanguard aircraft.

Fig. 2.—New Gecophone subscriber's telephone.

Higher-power units, using four transistors, give 160 watts output for operating four 40 W tubes, adequate for the lighting of one deck of an omnibus. The smallest unit, using one transistor, delivers 6 watts for a single 9-inch tube used in cars and caravans and as a bunk light in ships. Other units in an advanced stage of development enable transistors to replace rotary converters on aircraft. They are rated from 100 watts up to several kilowatts, both single- and three-phase, with a sine wave output at 400 c/s, and have the same efficiency as rotary machines.

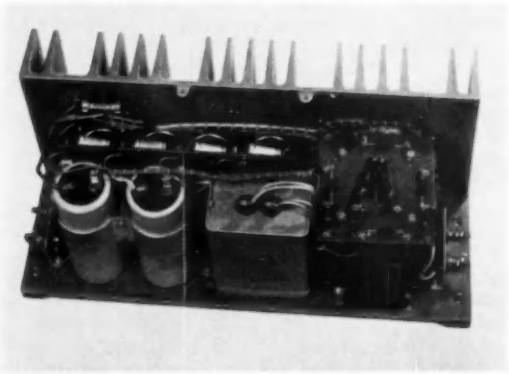


Fig. 3.—Transistorized inverter for operating fluorescent tubes.

Fig. 4.—Control console for automatic jig-boring machine.

Specialized control equipment for machine tools and other equipment includes one for the Newall jig borer, operated from punched cards, and first demonstrated at the Toronto Trade Fair in May (fig. 4). Static control equipment has also been manufactured which uses cold-cathode valves in place of relays and offers the opportunity to control an unlimited number of operations to a predetermined sequence and timing. Remote control systems have been developed for B.B.C. transmitters. These use tone-control signalling over V.H.F. communication links and include facilities for " reporting-back " and for eliminating the interference of stray signals on the same operating frequency.

The range of *AM* and *FM* mobile communication equipment has been redeveloped and engineered to meet the most recently introduced operating specifications. Requirements have arisen for a less costly system of communication over short distances, for example to crane drivers, and these have been met with an equipment which transmits by the modulation of a light beam (fig. 6). It uses a tungsten filament projector lamp and transistors, and has an effective range of half a mile in bright sunlight.

In collaboration with Computer Developments Limited, a company owned jointly by International Computers and Tabulators Limited and the G.E.C., new computer equipment is being designed and developed which is expected to lead in performance in this field.

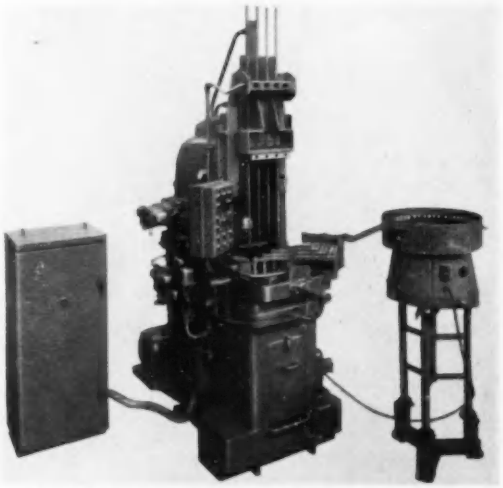


Fig. 5.—Automatic sequence control equipment for milling machine.

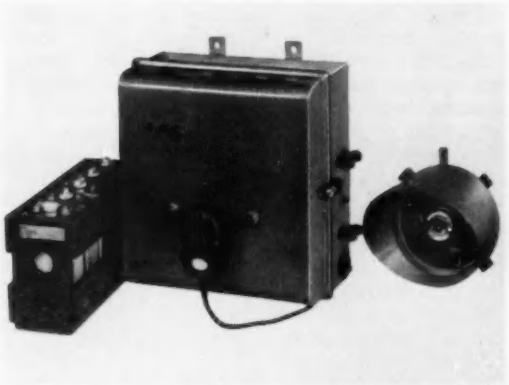


Fig. 6.—Communication equipment operated by modulation of light beam.

VALVES.

In the microwave-valve field further experience with the new electrostatically focused, backward-wave oscillator, the " Ophitron ", has confirmed the considerable potentialities of this rugged device in many applications (both commercial and military), particularly where a large bandwidth and good noise performance are advantageous. The present " Ophitron " tunes electronically over at least a 40 per cent band in the 10 000 Mc/s region and is the first of a range of valves covering most of the important centimetre wavelength bands. The noise performance is better than that of magnetically focused backward-wave oscillators, due to the ion drainage from the electron beam inherent in the focusing method employed, and the very small size and weight are of considerable interest. New types of travelling wave tube are being introduced with considerable emphasis on compact periodic focusing systems.

Among transmitting valves, two new, inexpensive, small valves have been introduced (TT21 and 22).

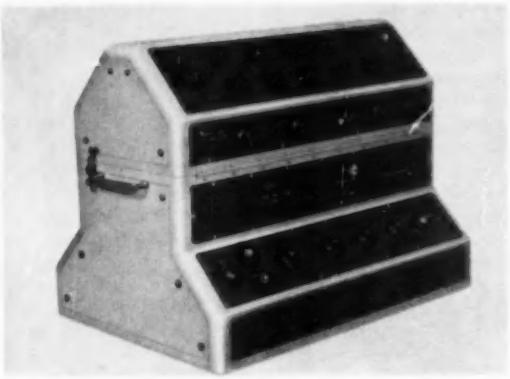


Fig. 7.—Cable harness routiner for aircraft installations.

These are variants of a basic type and will produce 100 watts output at frequencies up to 30 Mc/s. Another type with 150 W dissipation and a useful performance up to 500 Mc/s is being put into production. A large transmitting valve for broadcasting use, operating with an anode dissipation of 20 kW at frequencies up to 200 Mc/s, is in an advanced stage of development. It has a ceramic envelope and uses water-cooling. Considerable progress in the use of ceramic-metal seals in valve making has put the Company in a position to make ceramic-metal units for other branches of industry when the need arises.

In the receiving-valve field considerable emphasis continues on developments in the high figure-of-merit range and these include, in particular, a new high slope triode (E2754).

Increasing use is being made of hydrogen-filled rectifiers (such as E2788) incorporating the G.E.C. barretter-replenisher system, particularly for charging and inverse diodes in radar equipment. Deuterium-filled valves, first reported last year, have been found particularly useful as grid-controlled rectifiers and a new xenon rectifier has been developed for applications in which long life is of paramount importance.

SEMICONDUCTORS.

In the recently formed and increasingly effective Semiconductor Division, full advantage has been taken of the extensive development work of recent years to expand manufacture rapidly. Production efficiency has reached high levels and drastic reductions of costs have been made for devices which form the bulk of a fast-expanding and highly competitive market.

New processes have greatly increased the production yield of the GET 103 series of small audio transistors. At the same time the maximum junction temperature rating has been raised to 85 deg. C, a value 10 deg. C higher than that of all competitors' types in the United Kingdom. A second family, for which a large market already exists, is the GET 871 series of high-frequency transistors. These have been put into large-scale production and here again the developments in manufacturing processes have enabled costs to be brought down and ratings to be raised above those of competitors' types.

The year under review has also seen the full-scale production of the SX 63 750 mA silicon rectifier, the introduction of the GET 57 series of 12 ampere power-transistors and the exploratory production of the SX 75 8 ampere silicon rectifier. The low-noise-factor germanium microwave mixers, GEM 1 and GEM 2, were introduced and production of gold-bonded diodes, GEX 941 and GEX 951, has started. Preparations are well advanced for the manufacture of sub-miniature versions of the existing range of point-contact diodes, the SCR 96 silicon-controlled rectifier (which is rated up to 10 amperes at up to 400 peak inverse volts), and the EW 69 30 Mc/s high-frequency drift transistor.

Devices in development include a 30 Mc/s switching transistor (EW 93) in a design based on the drift transistor, and a 100 Mc/s drift transistor (EW 85). Much of the fabrication techniques used for both types is shared with those of EW 87 and EW 69, which makes for economy in manufacture. A new process, known as " Regrown Diffused ", has been developed at Wembley for the manufacture of an *n-p-n* medium frequency 10-20 Mc/s silicon transistor, EW 72.

Two variable capacitance diodes (EW 97 and EW 98) are being developed for parametric amplifica-

Fig. 8.—Automatic cable harness routiner for aircraft radar installations.

Fig. 9.—Transistor production lines at Hazel Grove factory.

RADIO AND TELEVISION.

In the Radio Division further advances in automatic assembly methods developed in the Radio Works helped to meet a considerably increased demand for its products. The entire range of television receivers is now produced on these unique assembly lines. The construction makes full use of plug-in printed circuits in a 16-valve receiver of high sensitivity with automatic picture control. The cabinet designs embody a radical breakaway from existing forms of television presentation. They are the first to take full advantage of the 110° cathode-ray tube, using shaped armoured glass to give a curved front line which accentuates the basic slimness of the design. Developments in radio receivers reflect the increasing popularity of transistor portables and the use of printed circuits in all types of receiver. A new FM-only transportable radio receiver also incorporates printed coils as a further development of the printed circuit technique.

In the field of high-quality sound reproduction two new developments in loudspeakers have been introduced. The first uses metal cone loudspeakers in an exclusive " Periphonic " acoustic push-pull system in a cabinet only 10 in. in depth with a bass response reaching 35 c/s. The second innovation is a " bookcase " type loudspeaker which achieves a remarkable standard of reproduction and has a bass response down to 40 c/s from a cabinet only 24 in. × 12 in. × 10 in.

tion at microwave frequencies. Their very low series inductance has been achieved by adopting a mechanical construction based on our microwave mixer crystals. At lower frequencies the characteristic variation of capacitance with voltage of the SX 761 diode is of interest in many applications.

Germanium mixer crystals in both polarities, suitable for balanced mixer systems in J-band equipment (16·5 k Mc/s), have been developed and production is being planned. Among high-speed switching diodes the types GEX 66, 39 and 951 together with SX 781 probably comprise the most complete range of diodes available anywhere.

To assist in the full exploitation of the wide range of devices available from the Semiconductor Division a team of applications engineers, based at the Wembley Laboratories but responsible to the Commercial Manager, offers its wide range of experience of electronic and electrical matters to the solution of customers' problems. Their work covers domestic applications such as broadcast radio receivers and tape recorders together with industrial switching and control circuits and all aspects of power supply problems, including power conversion, voltage and current stabilizers and overload protection. The team also plays its part in ensuring that devices are rated correctly and that they have characteristics suited as nearly as possible to the ideal requirements of their intended applications.

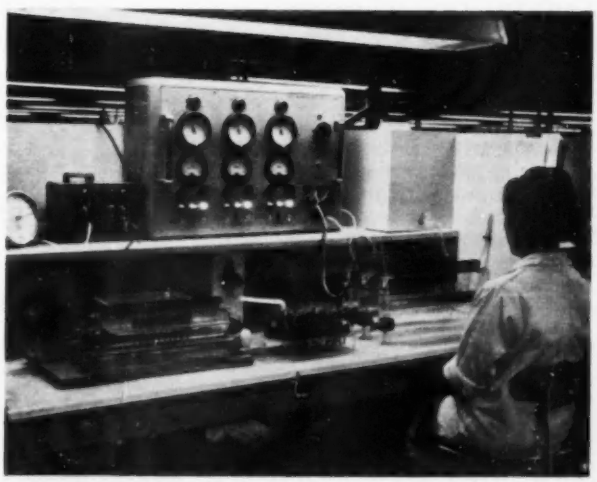


Fig. 10.—Electrolytic etch-cleaning of power transistors after alloying.

Re-motoring a Continuous Strip Mill

By J. T. MILLS, Chief Electrical Engineer, Ebbw Vale Section, Richard Thomas & Baldwins Ltd., and S. A. G. EMMS, Engineering Group, Witton.

In August, 1959, the continuous strip mill at the Ebbw Vale works of Richard Thomas & Baldwins Ltd. was completely re-motored in the remarkably short time of twenty days. The co-ordinated efforts of the R.T.B. engineers and outside contractors enabled this task to be accomplished ahead of schedule and the part played by the G.E.C. in this achievement is described in this article.

ON August 20, 1959, the continuous strip mill at the Ebbw Vale works of Richard Thomas & Baldwins Ltd. restarted rolling steel only twenty days after demolition gangs had moved in to rip out machinery which began turning nearly twenty-one years ago. This was one day ahead of the target date fixed before the operation started. In nineteen days, 1 500 tons of equipment had been removed and new machinery lifted in to take its place.

When the mill reopened it marked the completion of the major item in the second big post-war development programme at Ebbw Vale, aimed at increasing the output of top-quality steel sheet and tinplate, now in great demand for home and export markets.

The mill re-motoring was a triumph of co-ordinated effort between outside contractors and the mechanical, electrical and civil engineering departments of Richard Thomas & Baldwins. It involved the removal of much heavy machinery, the demolition of old foundations and the building of new, the lifting into place of more powerful and faster drives and the bringing into operation of an intricate control system.

Work started at 9 a.m. on Saturday, August 1, within minutes of the last strip passing over the old run-out table, and by the following morning more than 1 000 tons of motors, gears, pinions, housings and other equipment had been carried from the mill building. By the Sunday afternoon the first of the new pinion housings, weighing some 30 tons each, had been put in position and by Bank Holiday Monday all the eight pinion housings to be renewed on the roughing mills and six-stand finishing line were in place.

As foundations became available electric motors—the biggest weighing 120 tons—gearboxes and other major items were lifted in, ready for lining up and coupling. Meanwhile, work went ahead on electrical, cooling and lubricating systems and on August 19 everything was ready for an experimental start with the mill running light.

The following day the first slab was passed through, opening a new chapter in the story of Britain's first hot strip mill—a mill that had already rolled more than thirteen million tons of steel in peace and war. When it was laid down in 1938 it had a planned capacity of 12 500 tons a week : subsequent developments raised this to an average of 16 000 tons a week. Now, with its new electrical drives totalling

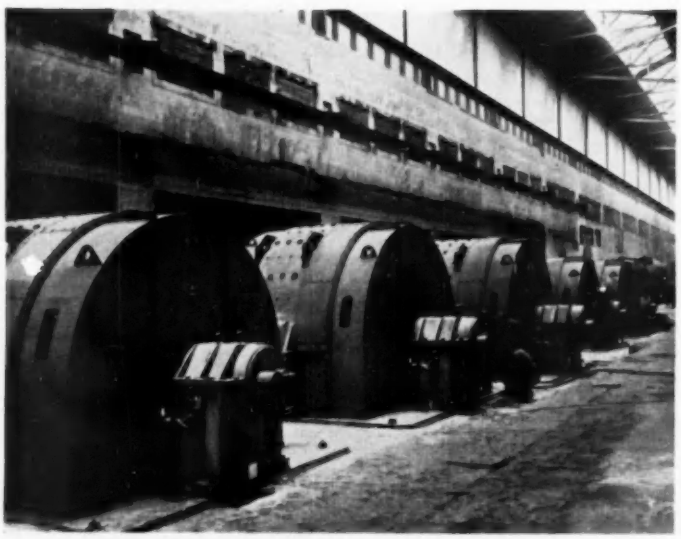


Fig. 1.—Five of the six main mill motors totalling 23 000 h.p.

36 000 horsepower, a further significant increase is anticipated.

McLellan & Partners were main consultants for both electrical and civil work, being assisted in the latter by W. S. Atkins & Partners. The principal contractors included The General Electric Company Ltd., Davy United Limited, and Sir Robert McAlpine & Sons Limited.

The order for the new electrical equipment for the repowering of the six-stand finishing mill was entrusted to the G.E.C. as main contractors in January, 1957. The task was exceptional in several ways, and its completion ahead of schedule reflected the goodwill and co-operation which prevailed throughout the life of the contract.

Five of the stands are now driven by 4 000 h.p. motors and the sixth stand by a 3 000 h.p. motor (fig. 1). All these were erected on temporary bases behind the existing drives and new power supply, converting plant and switchgear installed while the mill continued to run.

The mill is controlled from a new pulpit (fig. 2) from which the operator has a clear view of the rolling process. Accurate speed control is essential in order to avoid looping or stretching between the stands through which the strip passes at increasing speeds as its thickness is reduced, until it leaves the last stand at up to 2 000 ft/min. The operator selects, by means of his controls, the operation to be performed. From then on, the set-up of the various control components is automatically effected and checked, the completion of this sequence being displayed to the operator by indicating lamps.

The complete installation is covered by a comprehensive system of protective devices, and should a fault occur, visual signals show at a glance where the fault is to be found. In an emergency the mill can be brought to rest in four seconds by operating an " emergency stop " button.

Fig. 2.—Control pulpit for six-stand finishing mill.

Before considering in detail the equipment and its changeover problems, it may be of interest to compare the old and new installations. This information is given in Table 1.

In order to derive the maximum benefit from the diversity of loading on individual stands, and also to enable a portion of the rectifier equipment to be withdrawn from service for maintenance, it was

TABLE 1.

MAIN STAND DRIVES.

	Before Conversion.						**After Conversion.**						
Machine Data	F1.	F2.	F3.	F4.	F5.	F6.	F1.	F2.	F3.	F4.	F5.	F6.	Remarks
Type of drive	←		Geared			Direct	←	Geared	→	←	Direct	→	Nameplate Figures
Horsepower	←		3 375 each			2 800	←		4000 each			3 000	
Speed range rev/min	←		225 450 each			168/336	—	—	—	—	—	—	
ft/min	196/392	282/564	452/904	655/1310	783/1566	923/1846	211/473	328/738	554/1108	753/1506	905/1860	1053/2077	Figures based on roll sizes given below.
Max. roll size	←			21"		→	←		23"			→	
Weight (tons)	36	36	36	36	36	32	73	73	120	90	73	55	

decided to adopt the common bus system. This formed the basis for the layout of the new electrical plant, which for the rest was determined by the need to run the existing equipment uninterruptedly up to the last moment before the changeover. It was thus necessary to complete the installation beforehand, with the sole exception of substituting the new motors for the old.

ELECTRICAL EQUIPMENT.

The main components of the new equipment are :

1. The main drive motors.
2. Rectifiers and transformers.
3. Circuit breakers.
4. Copper busbars and cables.
5. Mill control.
6. Protection.
7. Instrumentation.

Main Motors.

It was decided that the new and larger motors would have to be erected on the motor-room floor behind the existing drives so that preliminary running tests could be carried out. When the time came they would have to be jacked on to skid rails, traversed and lowered on to new foundations. These foundations consist of a new supporting wall between the basement floor and the underside of the motor-room floor to support the non-driving end bearings of the new motors, together with a number of pre-cast concrete beams between this and a corresponding wall carrying the driving end bearings. The space between these walls is used as a ventilation chamber.

The main motors are of robust construction, particular attention having been given to the bracing of compensating windings and connexions. Commutators are enclosed and large doors in the end covers give access to them. Special care was taken to ensure that each machine could be moved as a complete unit, as necessitated by the changeover programme.

Flow lubrication is provided, with a large reservoir in the basement from which oil is pumped to each bearing through coolers and strainers. In addition, there is provision for continuous filtration of 15 per cent of the circulating oil by centrifuge filter. Standby pumps, coolers and centrifuges are also provided.

Each bearing has a visual flow indicator and a regulating valve and filter, and is also furnished with oil rings as a safeguard against a complete failure of the flow system.

The motors are forced-ventilated from the chamber already mentioned, air entering the driving end. About 10 per cent of the volume is fed over the commutators and ducted away to remove carbon dust, while the remainder is recirculated through the cooler. Make-up air enters through filters. Air supply is maintained by a total of five axial-flow fans, of which four are sufficient to deliver the 108 000 ft^3/min needed by the stand motors and existing scale breaker motor.

Rectifiers and Transformers.

The original hot-mill roll shop beyond the northern end of the motor room was cleared and rebuilt to house 19 800 kW of rectifiers, the associated transformers being accommodated in pens facing into the adjacent sheet bay. Part of the rectifier installation is shown in fig. 3. Ventilating fans and heaters are installed to keep the rectifiers at working temperatures under all climatic conditions.

Supplies to the rectifiers are controlled by 11 kV 500 MVA switchboards. Individual breakers control each of the six transformer/rectifier groups. The rating of the installation is such that full mill output can be maintained with five of the six groups in service. Each group comprises four cylinders arranged in pairs which share a common d.c. circuit breaker. Provision is thus made for disconnecting any one pair.

Each group transformer is rated at 3 300 kW and comprises two units in a common tank. One unit has a 3-phase star-connected primary winding, the other being delta-connected. These are associated with four secondaries to give a 12-phase output at an r.m.s. voltage of 810 V. Each primary also excites a tertiary winding to supply rectifier excitation and arc-suppression circuits. In order to avoid excessive harmonic interference being introduced into the supply system, the complete installation is arranged to give 36-phase rectification.

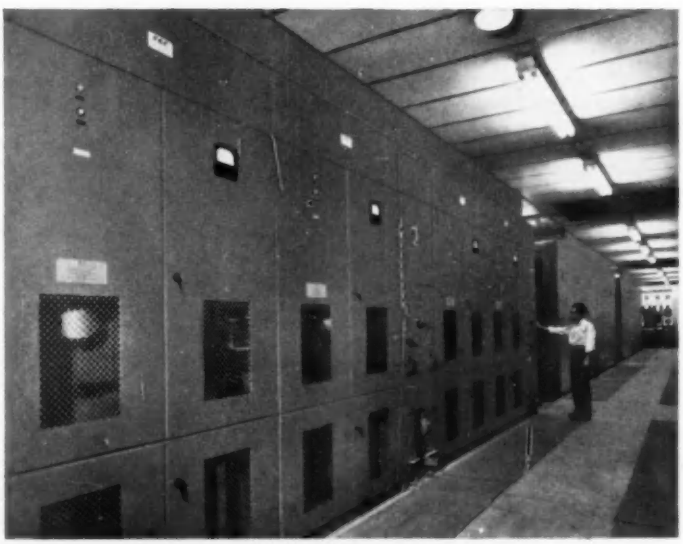


Fig. 3.—Part of the 19·8 MW rectifier installation.

A 240 kW loading resistor is provided by means of which the complete rectifier installation can be tested during a mill shut-down, without interfering with machine maintenance. In addition a smaller resistor is available for the individual testing of any one rectifier group while the remaining five are on load with the mill running.

D.C. Circuit Breakers.

On the d.c. side, the equipment is protected by truck-type high-speed circuit breakers. Those associated with the rectifiers are of 3 000 A capacity and, in order to avoid duplication of spares, two of these units are used in parallel in each motor circuit. Load sharing in the motor circuits is ensured by special arrangement of the copper work and is monitored by ammeters located near the breakers.

Busbars and Cables.

More than 60 tons of copper work was involved. This is more than usually extensive, even for such a large installation, because of the distance between the rectifiers and motors. The choice of routing was restricted and did not permit wide separation between poles. Attention had, therefore, to be given to mechanical strength, since the short-circuit capacity is very high.

The difficulty of choosing optimum cable routes was also much increased by the wide separation of the plant components, and by the inevitable restrictions imposed by the use of an existing building.

Mill Control.

The six motors are accelerated simultaneously by raising the d.c. busbar voltage by grid control of the rectifiers, speeds of the individual stands being adjusted as necessary by altering the excitation of the stand motors.

For running the mill it is first necessary to select, by the pulpit controls, the operation to be performed, namely, inching, slow running, lining up, or rolling. On selection of the required operation, the set-up of the various control components is automatically effected and checked, and the completion of this sequence is displayed to the operator by indicating lamps. The first three operations named are at a low speed which is determined by the busbar voltage. This voltage is maintained by an automatic voltage regulator comprising a high-accuracy, quick-acting magnetic amplifier, controlling the grid phase-shift network (fig. 4).

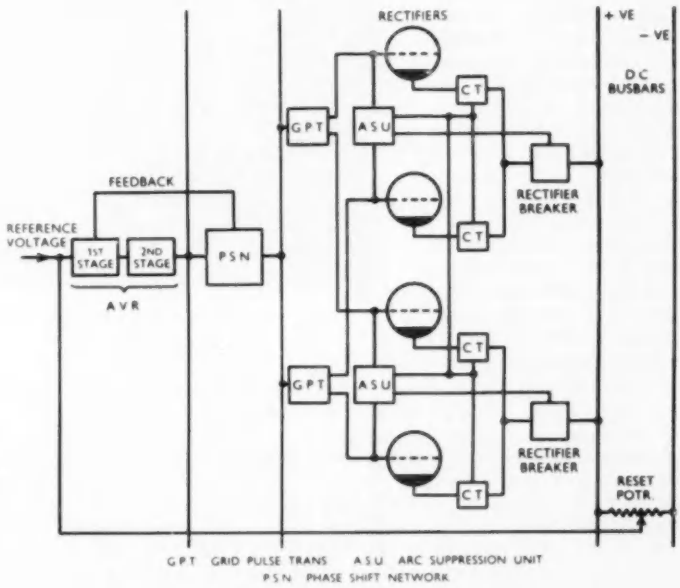


Fig. 4.—Simplified diagram of automatic control of d.c. busbar voltage.

Rolling is effected at full voltage, maintained as described above by the a.v.r. The stand drive includes a current-compensating feature to control the motor characteristics. Hand verniers on the pulpit desk give quick-acting speed correction. A common "emergency stop" button brings all mill main drives to a standstill in four seconds under dynamic braking control, which is applied automatically in three stages.

Since the rectifiers cannot accept reverse power, resistors are provided to absorb the stored energy of the rotating parts when speed is reduced either by strengthening of stand motor fields or by decreasing the busbar voltage.

A simplified version of the main power and control circuits of one of the stand drives is shown in fig. 5.

PROTECTION.

A comprehensive system of protection has been evolved to cover the lubrication and ventilating systems as well as the main electrical circuits and mill safety devices.

The 11 kV incoming circuit breakers have time-lagged overloads backed up by high-set instantaneous trips to protect against short-circuit faults. Time-lagged under-voltage relays are also provided, together with earth-fault protection. Twelve sets of double Buchholz equipments protect the main and phase-displacement transformers and reactors.

Rectifiers are equipped with high-speed arc suppression, initiated by d.c pulse transformers in the cathode connexions ; this is primarily intended as a safeguard against backfire, on the occurrence of which all four rectifiers of a group are suppressed. Indication of the back-firing tank is given. The associated d.c circuit breaker (which will have been tripped because of reverse current at the time of the back-fire) is reclosed automatically, but remains locked out if the third successive attempt to reclose has proved unsuccessful. A successful auto-

Fig. 6.—Supervisory panel in motor room.

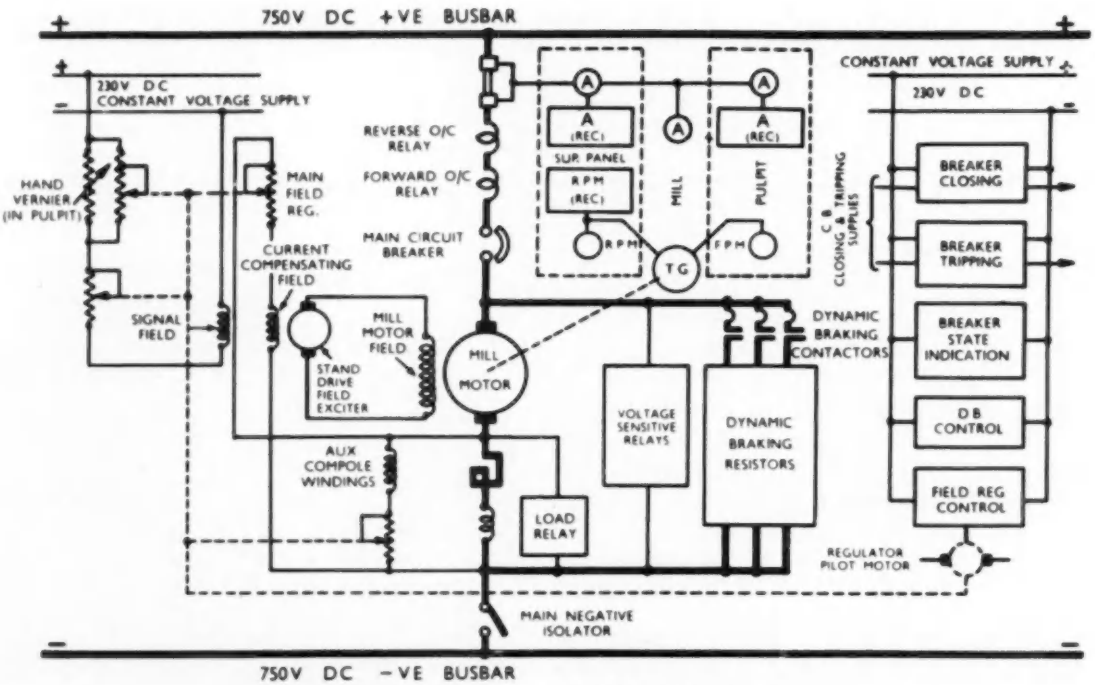


Fig. 5.—Main power and control circuits of one of the stand drives.

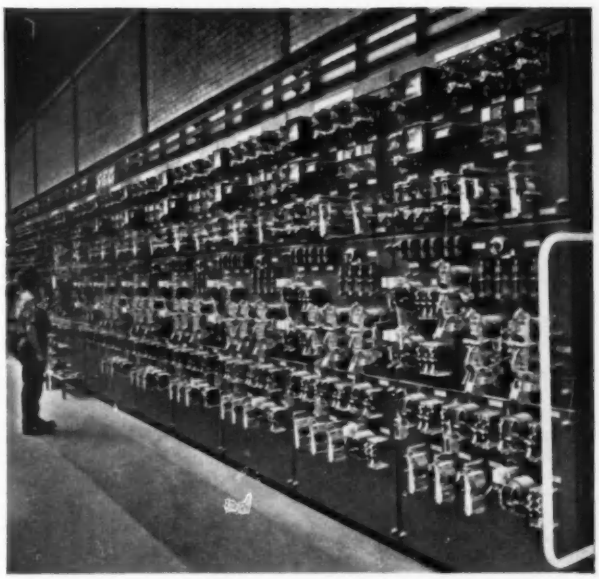


Fig. 7.—One of the contactor control boards.

matic reclosure releases arc suppression. Failure of an individual rectifier auxiliary (e.g. fan, ignition or excitation) applies arc-suppression to the pair.

D.C. circuit breakers, in addition to the independently adjustable reverse-current feature mentioned above, are fitted with high-set instantaneous trips and also with thermal overload trips.

The alarm annunciators, which give audible warning that any protective device has operated, have visual signals grouped so as to show at a glance which of the following plant sections is faulty :

(*a*) 11 kV circuits.
(*b*) Rectifiers.
(*c*) D.C. busbars.
(*d*) Machines and air-cooling system.
(*e*) Mill lubrication systems.
(*f*) General (e.g. fire alarms, etc.).

The alarms are planned to guide the maintenance staff at once to the affected " district ", and to pin-point the defective machine or equipment.

Instrumentation.

Mill instrumentation generally is concentrated at the supervisory panel in the motor rooms, with essential records and indications duplicated in the mill pulpit. At the supervisory panel (fig. 6) the availability of all essential supplies is indicated together with the state of all d.c. circuit breakers. Stand-drive armature currents and speeds are both indicated and recorded, and the temperatures of stand-drive bearings, their lubricating oil, and the cooling water are available by operating a multi-point indicator. Field currents, both of the main drives and their associated control exciters, are also shown. In the pulpit the roll speed of each stand is shown in feet per minute and stand-drive armature currents are indicated and recorded.

CHANGEOVER.

As previously stated, the original drive was kept in service until 9 a.m. on August 1, when the changeover began. Preparations for the new drives had necessitated moving two of the three motor-generators supplying the original mill drives.

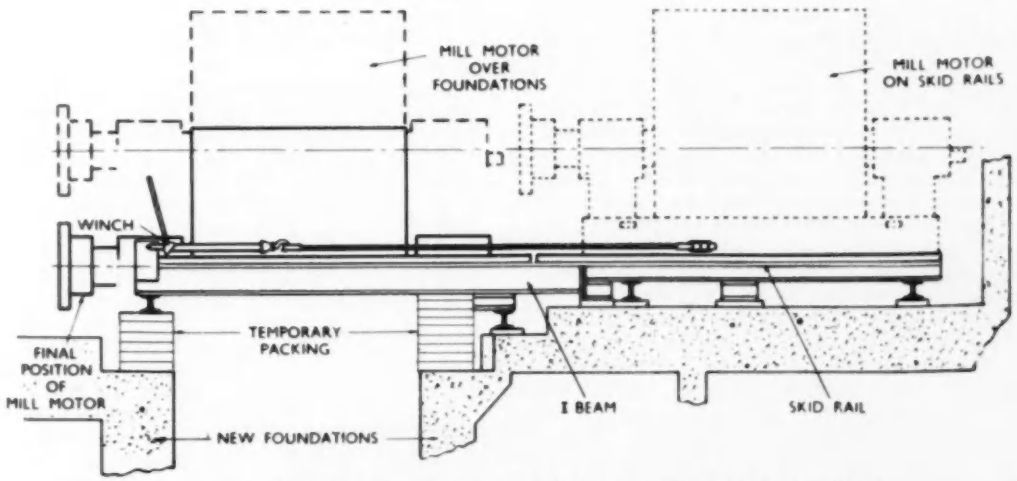


Fig. 8.—Method of traversing and lowering the new motors on to their foundations.

One set was taken out of commission completely, and another removed bodily on to new temporary foundations, during the August holiday shut-down of 1958. At the same time, all the original stand-drive d.c. circuit breakers were transferred from their positions in the basement to sites adjacent to the motor foundations, and a temporary 500 V d.c. copperwork and cable system was installed.

This left room for the new 750 V main circuit installation and cooling system to be erected and partly commissioned prior to the 1959 changeover. During the period May/June, 1959, the new machines were erected behind the existing motors upon temporary bases built up from structural sections, as shown in figs. 8 and 9. As soon as the existing drives were removed and the foundations reconstructed, slideways consisting of heavy I beams, topped by railway rails and supported by twin stacks of packing, were erected across the space between the two supporting walls. Next, the new motors were jacked up to allow rails to be placed between the tops of the temporary bases and the motor bedplates, these rails being at the same level as those of the slideways. The motors were now ready to be traversed into position above their new foundations, a movement which was effected by means of winches secured to hauling lugs on the motor baseplates. The operation was completed by lowering the motors vertically on to the new foundations. This was carried out by a " leap-frog " process, in which each motor was temporarily supported while a section of packing was removed.

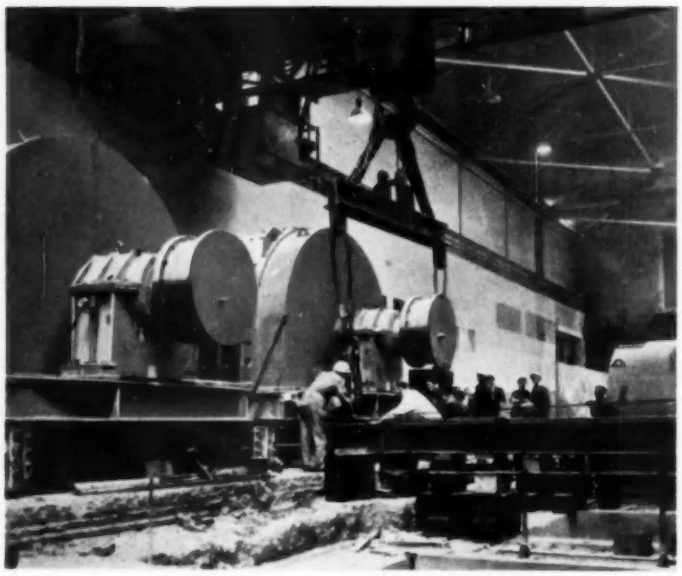


Fig. 9.—Traversing one of the new stand motors.

The total weight of the motors thus moved was 484 tons, the largest unit weighing 120 tons. Motor baseplates had been specially designed to withstand without distortion the abnormal horizontal and vertical forces involved in the move and were also provided with lugs and lifting pads where these would facilitate the work. Accurately machined and calibrated surfaces near each bearing greatly simplified the final lining up and coupling.

ACKNOWLEDGEMENT.

Acknowledgement is due to Richard Thomas & Baldwins Ltd. for permission to publish this article and the accompanying illustrations.

The G.E.C. Cross-Flow Fuel Element

By M. C. HARTNELL-BEAVIS, B.Sc.,
Atomic Energy Division.

Brief details of the cross-flow fuel element were given in an article on "A Nuclear Reactor Installation for Marine Use", published in the Autumn 1959 issue of the "G.E.C. Journal". In the present article a full description of the design of the new fuel element is given, together with data on its performance.

INTRODUCTION.

A NEW fuel-element design for advanced gas-cooled reactors fuelled with uranium dioxide has been developed in the Erith laboratories of the G.E.C. Atomic Energy Division. The main objective has been to realize the high development potential of the gas-cooled, graphite-moderated reactor, particularly for installations of small power output in the range 30 to 100 MW(e), for both land and marine applications. The particular considerations leading to the design, a description of the currently proposed fuel element, and data on its performance, are given in the following account.

CHOICE OF MATERIALS.

The economic optimization of reactor fuel elements involves a compromise between engineering design and the nuclear and physical properties of materials. The main factors affecting the choice of materials for fuel elements are :

(*a*) chemical compatibility between fuel, canning, coolant, moderator, and—under extreme fault conditions—air ;

(*b*) physical and mechanical properties and their variation with temperature ;

(*c*) nuclear properties—absorption, fission, and scattering cross-sections, and radiation effects.

These properties must be related to the optimum heat-transfer and pressure-drop configuration, and to simplicity of production and assembly, with the ultimate objective of reducing fabrication and running costs to a minimum.

Unfortunately, the α-β phase transition in uranium metal at 660 deg. C marks an absolute limit to the operating temperature for metallic fuel elements. The gain in efficiency and the reduction in size and cost of both the generating plant at higher temperatures and the reactor at higher fuel ratings provide the incentives for the development of fuels and canning with higher melting points. Of the possible high-temperature fuels, only uranium dioxide could be regarded as having a sufficiently firm basis of established technology to be put forward for current reactor proposals. To justify the use of this oxide, which entails enrichment owing to its low density, high values of reactor rating and coolant outlet temperature are necessary. The only currently used canning material compatible with carbon dioxide at high temperatures and having suitable other properties is stainless steel.

DEFINITIONS.

In order to clarify subsequent discussion, the following description explains the various terms that are used :

Uranium dioxide is at present manufactured in the form of small *pellets* which are inserted into the stainless-steel *can*. The assembly of pellets, *spacers* if any, can, and *end caps*, forms a fuel *capsule*. A number of capsules are supported in a graphite *sleeve* and the composite structure of sleeve and capsules is called a *fuel element*.

TABLE 1.

Properties of the fuel-element materials

	Uranium dioxide	18/8 stainless steel	Magnesia
Melting point, °C	2 760	1 450	2 800
Thermal conductivity, cal/cm s deg. C	0·019 (200°C) 0·008 (1 000°C)	0·039 (100°C) 0·057 (700°C)	0·082 (100°C) 0·026 (600°C)
(irradiated)	(0·004)		
Coefficient of linear expansion per deg. C (100°C)	9×10^{-6}	$16{\cdot}5 \times 10^{-6}$	11×10^{-6}
(500°C)	11×10^{-6}	18×10^{-6}	13×10^{-6}
Theoretical density, g/cm³	10·968	7·9	3·58
Young's modulus (20°C), lb/in²	25×10^{6}	28×10^{6}	12×10^{6}
kg/cm²	$1{\cdot}8 \times 10^{6}$	$2{\cdot}0 \times 10^{6}$	$0{\cdot}8 \times 10^{6}$
Poisson's ratio (100°C)		0·29	
(500°C)		0·32	
Ultimate tensile strength, lb/in² (400°C)		65×10^{6}	
(600°C)		46×10^{6}	
kg/cm² (400°C)		$4{\cdot}6 \times 10^{6}$	
(600°C)		$3{\cdot}2 \times 10^{6}$	
Thermal-neutron absorption cross-section, cm²/cm³	0·165	0·247	0·0038

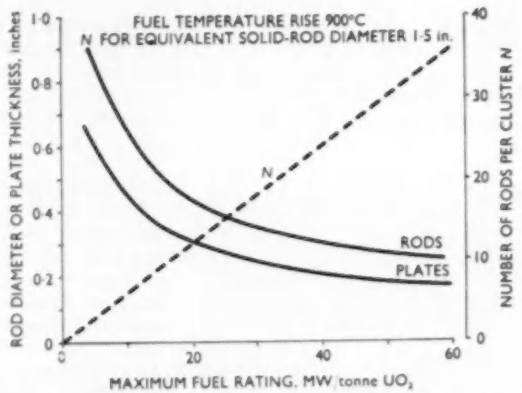


Fig. 1.—Dimensions of fuel capsules and number of rods required in a cluster for different fuel ratings.

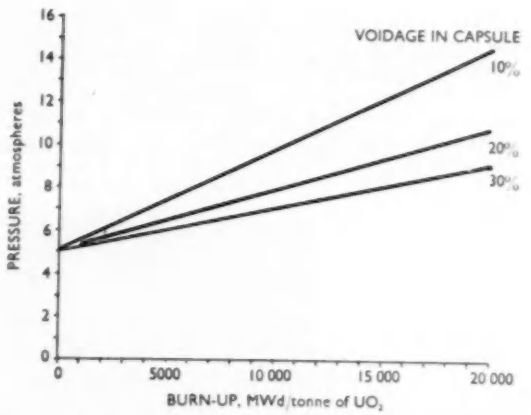


Fig. 2.—Increase with increasing burn-up of internal gas pressure due to fission-product gases.

DESIGN LIMITATIONS.

Some properties important to fuel-element design are listed in Table 1, for a number of materials, and the following are particularly relevant :

Thermal Conductivity and Melting Point.

The low thermal conductivity of the oxide, particularly under irradiated conditions, necessitates short thermal paths between the centre and the surface of the oxide pellet. Fig. 1 shows the thickness of uranium-dioxide plate, or diameter of rod, as a function of fuel rating for a temperature rise in the fuel of 900 deg. C, assuming uniform rating and uniform conductivity of 0·004 cal/cm deg. C.

Dimensional Stability and Behaviour Under Thermal Shock.

Uranium dioxide is completely stable to very high irradiations (in excess of 30 000 MWd/t). At the ratings under consideration (greater than 10 MW/t) the thermal gradients in the fuel pellet are of the order of 3 000 deg. C/in. (118 deg. C/mm), resulting in the formation of irregular cracks throughout the oxide. Thus in the irradiated condition, although the pellets are capable of resisting compression, complete structural support must be provided by the canning.

Retention of Fission-Product Gases.

The ability of the oxide to retain fission-product gases is a function of its density. Fission-product gas release reaches a minimum with the oxide density about 95 per cent of its theoretical value. A high release of fission-product gases occurs on melting of the oxide, but from safety studies of proposed fuel-element designs, it is clear that under any conceivable fault conditions the can would in all cases melt before the oxide. For design purposes it is therefore safe to assume no melting. Experimental results indicate a maximum release inside the can of 5 per cent of the fission-product gases, and the growth of internal pressure in the capsule with time is then as shown in fig. 2, for various voidages in the fuel capsule. Fig. 3 shows the temperature rise across the interface gap between oxide and can ; it is clear that close tolerances are required in the manufacture of the oxide pellets. One limitation on fuel-capsule life can be arbitrarily set at the point where internal pressure equals the normal operating external pressure of the coolant. Increase beyond this would give rise to local lifting of the can, with a sharp increase in the centre temperature of the oxide—as can be seen from fig. 3.

FUEL-ELEMENT GEOMETRY.

The above physical limitations to fuel-element design allow a number of practical geometrical configurations. To provide resistance against lifting of

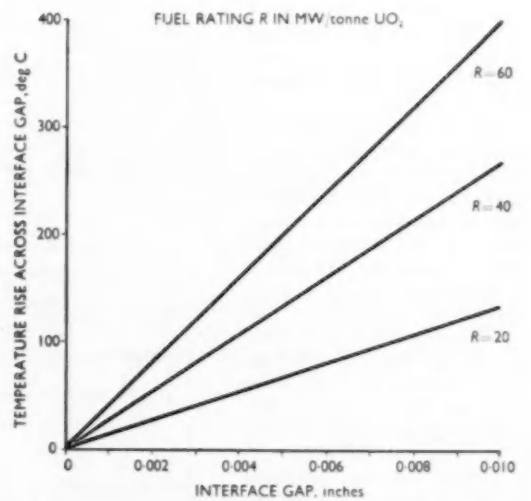


Fig. 3.—Temperature rise across interface gap for various fue ratings (helium filling, capsule dimensions 1·0 in. × 0·25 in.)

the can off the oxide surface, it is desirable that the surface of the can should be everywhere convex, which suggests that the capsules should be in the form of rods rather than flat plates. From nuclear considerations it is necessary to design to an optimum quantity of uranium dioxide per unit length of channel —equivalent to a solid oxide rod of about 1·5 in. (38 mm) diameter. The fuel must therefore be subdivided, and bundles of small-diameter rods in longitudinal flow have been proposed, for example, in the American GCR design.[1]

The approximate number of solid rods in such a cluster as a function of rating (again assuming a temperature rise of 900 deg. C in the fuel), is shown by the dotted line in fig. 1.

Longitudinal-Cluster Design Problems.

It can be appreciated that in highly rated reactors there are a number of formidable design problems. To reduce the number of rods, it has been proposed[1] to make the pellets hollow. Under operating conditions of thermal cracking and possible spalling of the oxide off the internal face, this would not only give a highly undesirable reduction in capsule strength but might also result in melting due to the poor heat conduction from isolated fragments. The supports for the rods in the cluster introduce large pressure drops, they are complicated and difficult to assemble, and their complexity and the associated pressure losses increase rapidly as the rating and hence the number of rods in a cluster increase. Bowing of the rods is caused by the thermal-neutron flux gradient across them, by uneven distribution of coolant flow, or by any one of a number of manufacturing faults ; this bowing is increased by the resulting flow restriction, and the spacing and rigidity of the supports must take this possible instability into account. In addition, a very poor heat-transfer/pressure-drop characteristic is obtained with smooth rods in longitudinal flow, although an increase in heat-transfer efficiency can be obtained by using a roughened surface to break up the laminar boundary layer of coolant. The canning must be made as thin as possible consistent with mechanical and corrosion considerations, and the addition of roughness in the form of circumferential ridges to a stainless-steel can only 0·010 in. (0·25 mm) thick involves a difficult and costly manufacturing process. Owing to the relatively high neutron-absorption cross-section of stainless steel and its low conductivity, finning with this material is not profitable. A further problem is the promotion of bulk mixing of the coolant between rods in a closely packed bundle, to compensate for the radial variation in thermal-neutron flux and hence in heat production across the channel.

THE G.E.C. CROSS-FLOW FUEL ELEMENT.

General Considerations.

The new fuel-element design which has been produced by the G.E.C./Simon-Carves group overcomes most of these difficulties. Initially, a study was made of the potentialities of *cross flow* over banks of round

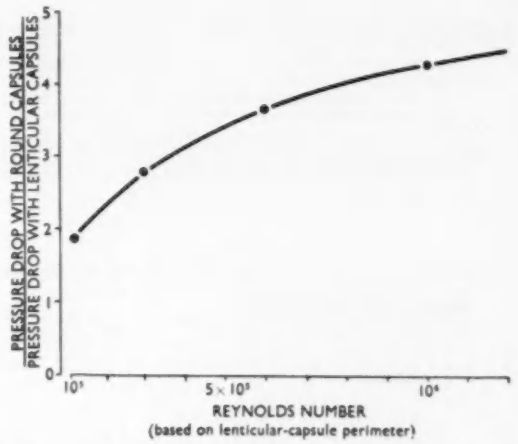


Fig. 4.—Ratio of pressure drop across smooth round capsules to that across smooth lenticular capsules (in-line configuration in cross flow).

rods, for which adequate heat-transfer and pressure-drop data were reported in the literature. Excellent heat-transfer characteristics are obtained owing to the breaks in the boundary layers in the direction of coolant flow, but this is accompanied by a very high pressure drop. This pressure drop is mainly due to form drag, which contributes little to heat transfer and may represent up to about 95 per cent of the total pressure losses. With smooth rods of a given perimeter in cross flow, heat-transfer properties are not greatly affected by change of shape ; the problem was therefore simply to reduce the form drag by streamlining the shape in the direction of coolant flow. No previous experimental data for banks of streamlined tubes in cross flow were available. The first experiments were therefore designed to study the effects of varying the cross-sectional shape.

These initial experiments gave very encouraging results. A comparison between smooth round tubes

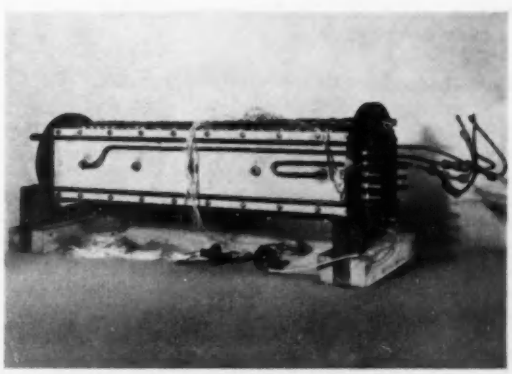


Fig. 5.—Experimental channel for obtaining heat-transfer data.

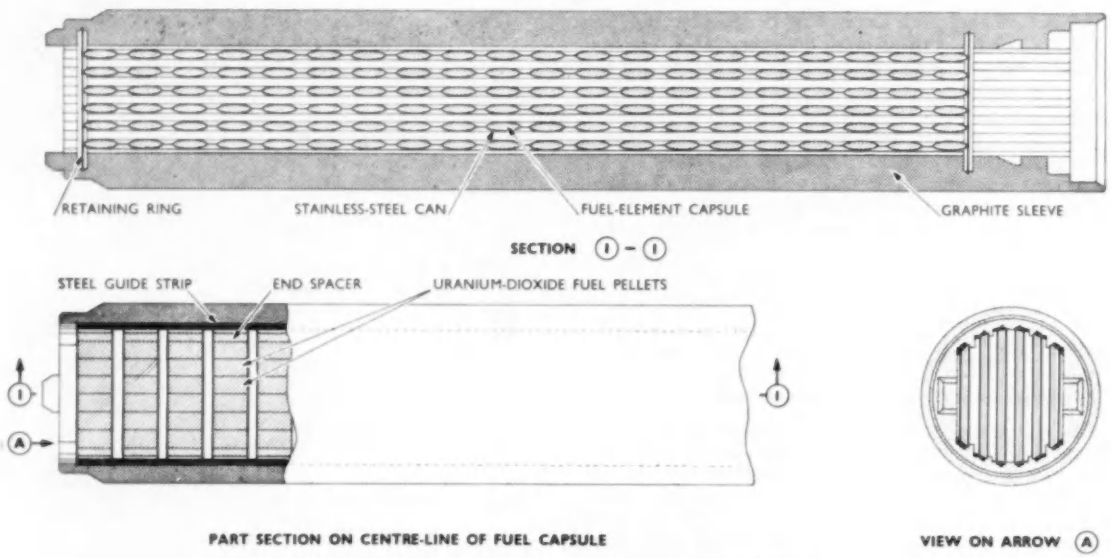


Fig. 6.—Drawings of a typical design of cross-flow fuel element.

and lenticular tubes (ratio of major to minor axis 3 : 1), both in cross flow, is given in fig. 4, in which it is assumed that the following parameters are the same in both cases :

(*a*) the channel cross-sectional area and channel length ;
(*b*) the surface area of capsules per unit length of channel ;
(*c*) the volume of oxide per unit length of channel;
(*d*) the channel temperature rise, mass flow, and heat output.

It can be seen that at normal design Reynolds numbers ($>10^6$), the channel pressure losses drop by more than a factor of four for lenticular-shaped capsules.

Selected cases have been tested in a pressurized CO_2 experimental rig. Fig. 5 shows the experimental channel used to provide data for the initial design of fuel element used in the marine installation described in the previous issue.

Typical Design of Cross-Flow Fuel Element.

A representative design of cross-flow fuel element is shown in fig. 6. The uranium-dioxide fuel pellets are canned in 0·010 in. (0·25 mm) thick 18/8 stainless steel. The dished end caps are heliarc welded (seam welded) on to the oval can, and the end caps are protected from excessive temperatures during operation by porous magnesia inserts. Steel guide strips of the same order of thickness as the cans are welded to either end of a number of capsules to form a ladder-shaped assembly.

The channel in the graphite sleeve is broached to the required shape, with grooves and slots into which these capsule ladders are inserted. Steel retaining rings sprung into grooves near each end of the sleeve hold them in position. The projections and keys providing axial sleeve alignment, and the slots used for charge/discharge are also shown on fig. 6. A photograph of a prototype fuel element is shown in fig. 7.

It is of interest to quote some design results for particular cases. It must be emphasized that although these results are based on experimental values, continuing development at the G.E.C. laboratories is resulting in considerable gains in performance, and both heat-transfer configuration and mechanical design can undoubtedly be greatly improved. In Table 2, typical design values for various fuel ratings are given. As can be seen from fig. 1, the higher the rating the smaller the size of capsule, and optimiza-

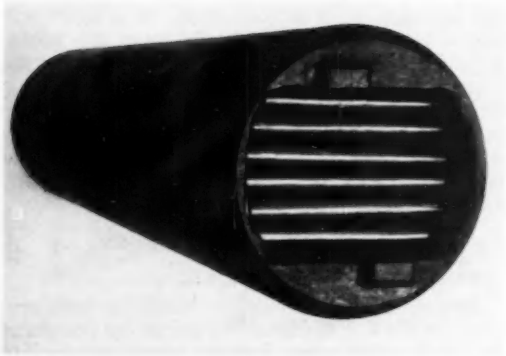


Fig. 7.—Prototype cross-flow fuel element.

tion must take into account the cost of the additional enrichment entailed by the added canning absorption and smaller size reactor. The more highly rated example quoted in Table 2 is for a coolant pressure of 400 lb/in² (28·1 kg/cm²); for a given fraction of the thermal output expended in circulating the coolant, rating is directly proportional to coolant pressure. It will be appreciated that by increasing the coolant pressure very high ratings are possible in special applications, the upper limit being imposed by safety in transient behaviour and by economic considerations.

Table 2 also gives interesting comparisons between oxide fuel elements in cross flow, smooth oxide fuel elements in longitudinal flow, and finned natural-uranium-metal elements as used in one of the reactors currently being built for the British nuclear power programme. The data for oxide fuel elements in longitudinal flow were calculated from the published figures for the United States Kaiser-ACF gas-cooled reactor design.[1] It is not easy to compare directly different design data. However, channel output is approximately proportional to mass flow of coolant, and pressure drop to the square of the mass flow. For channels of the same length, inlet temperature, and outlet temperature, a rough comparison of performance may therefore be made on the basis of the values of the quantity :

$$\frac{(\text{channel output})}{(\text{heated surface area})} \times \frac{(\text{channel output})}{(\text{channel pressure drop})}.$$

Conditions for the 760 kW output cross-flow channel and the 670 kW output longitudinal-flow channel are similar ; comparing these on this criterion gives an advantage to the cross-flow element by a factor of three.

TABLE 2.

Typical cross-flow channel performances, compared with those for other designs.

(1) & (2) G.E.C. cross-flow fuel element.
(3) Kaiser-ACF design.
(4) Hunterston centre channel.

	(1)	(2)	(3)	(4)
Channel output, MW	0·760	2·3	0·67	0·2
Channel rating, MW/t UO_2 ...	12·2	31	12	2·2*
Capsule major axis, in.	1·2	0·8	—	—
mm	30·5	20·3	—	—
Capsule minor axis, in.	0·3	0·2	—	—
mm	7·6	5·1	—	—
Pellet outside diameter, in. ...	—	—	0·705	—
mm ...	—	—	17·9	—
Pellet inside diameter, in.	—	—	0·323	—
mm ...	—	—	8·2	—
Capsule outside diameter, in. ...	—	—	0·750	—
mm ...	—	—	19·1	—
Number of capsules per row ...	6	8	—	—
Number of rods per cluster ...	—	—	7	1
Capsule longitudinal pitch, in. ...	2·45	1·01	—	—
mm ...	62·3	25·6	—	—
Sleeve outside diameter, in. ...	6	6	4·25	4·9
mm ...	152	152	108	124
Channel length, ft	13·5	10	14·5	23
m	4·11	3·05	4·42	7·02
Heated surface per channel, ft² ...	28	52	19	7†
m² ...	2·6	4·8	1·8	0·6
Coolant inlet temperature, °F ...	482	500	450	400
°C ...	250	260	232	204
Coolant outlet temperature, °F ...	1 000	1 000	1 000	735
°C ...	538	538	538	390
Coolant inlet pressure, lb/in² abs.	285	400	405	150
kg/cm² ...	20·0	28·1	28·5	10·5
Channel pressure drop, lb/in² ...	4·5	25	16	3·8
kg/cm² ...	0·31	1·75	1·13	0·27

* per tonne U † excluding fin area

Economics.

The assessment of the economic advantages to be gained by the new fuel element, with its lower pressure drop, simple construction, and high rating potentiality, is very complex. Interest rates on capital investment vary widely between different countries ; fuel enrichment and fabrication costs differ between the United States and the United Kingdom, as do fuel processing and buy-back costs. In particular circumstances a high emphasis is laid on low capital investment. Economic optimization involves a balance taking these factors, together with the expected load factor and proposed fuel cycle, into account. It may be assumed that fuel running costs based on United Kingdom fuel prices for $2C_0$ enriched oxide fuel with an expected burn-up of 10 000 MWd/t are very approximately equivalent to natural-uranium-metal fuel costs with a burn-up of 3 000 MWd/t. On this basis the lower capital cost of the more highly rated oxide-fuelled system represents a clear gain.

EXPERIMENTAL VARIABLES.

Capsule Cross-Sectional Dimensions.

The length of the minor axis is fixed by the permissible temperature rise in the oxide, while a number of considerations affect the ratio of the major to minor axes. The radius of curvature towards the trailing edge effects the " breakaway " point, and this has a marked effect on pressure drop ; as the major-to-minor-axis ratio is increased from unity (circular rods) the pressure drop may be expected to fall at first as the breakaway point moves towards the trailing edge. At large values of the ratio, the radius of curvature at the leading and trailing edges become of importance ; for example, relatively high pressure

drops occur with flat plates with semi-circular leading and trailing edges, owing, presumably, to the occurrence of breakaway near the leading edge. A further consideration is the strength of the can under irradiated conditions with a high internal fission-product-gas pressure. From this point of view, a "lenticular" section with capsule sides of constant radius of curvature and leading and trailing edges of small radius is desirable.

Capsule Length and Channel Size.

The channel size is determined mainly by ease of handling, the effect on reactivity of neutron streaming, and the reactivity effects which can conveniently be accommodated by the control system on discharging a channel. From an economic standpoint, the larger the channel, and hence the longer the capsules, the smaller the manufacturing costs and number of end caps per tonne of fuel.

Capsule Lateral and Longitudinal Pitch.

If the capsule cross-sectional dimensions and the channel size are fixed, performance must be optimized with respect to the number per row and hence (since the quantity of oxide per unit length of channel is given approximately by nuclear considerations) the longitudinal pitch. These are determined by the required outlet temperature and output per channel for a given channel length.

Capsule Surface.

For the cross-flow element, "roughening" by means of small ridges along the length of the cans is comparatively easy to fabricate by extrusion. Experiments show a considerable gain in heat transfer, but at the expense of a large increase in friction factor. In general, however, an improvement in channel performance is achieved, that is, a reduction in channel pressure drop for a given channel output and temperature rise. Fig. 8 shows typical experimental results giving a comparison between roughened and smooth surfaces.

The continuing experimental programme is designed to serve as a basis for optimization of these variables to suit a specific design. In addition, peripheral temperature variation and the effects of fine structure in the thermal-neutron flux must be taken into account in assessing performance. Measurements of peripheral temperature variation in a specific case have shown no significant changes round the surface except for a slight drop towards the leading edge.

A further variable which has not so far been mentioned, since it is not applicable to stainless-steel canning, is the addition of finning. Circumferential fins might be advantageous with canning of low neutron-absorption cross-section, such as impermeable graphite.

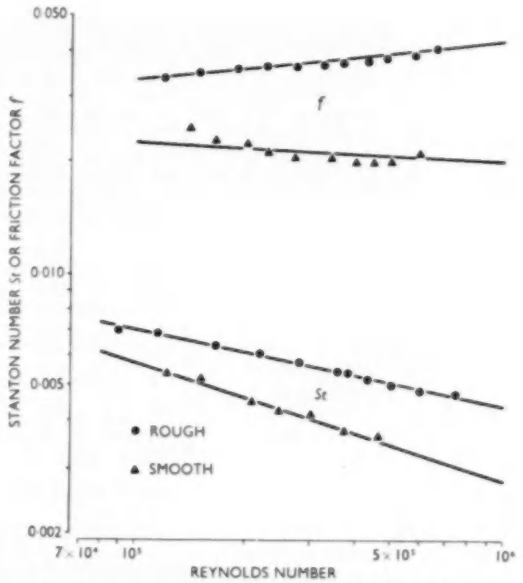


Fig. 8.—Typical heat-transfer results for cross-flow fuel element with rough or smooth lenticular tubes.

$$\frac{\text{Transverse pitch}}{\text{Minor axis}} = 2{\cdot}26, \quad \frac{\text{Longitudinal pitch}}{\text{Major axis}} = 1{\cdot}45, \quad \frac{\text{Major axis}}{\text{Minor axis}} = 3.$$

CONCLUSIONS.

The results quoted show that the G.E.C. cross-flow fuel element represents a significant improvement in fuel-element design. In comparison with longitudinal clusters at the same rating, channel output, and temperature rise, the pressure drop is approximately halved at low ratings (10 MW/t), with an increasing advantage at higher ratings. Although of general application, the advantages of this fuel element are particularly significant for small, highly rated, reactors, and have already made possible the design of a graphite-moderated gas-cooled reactor for marine use.[2]

These current experimental results will undoubtedly be greatly improved under the extensive optimization programme which is being carried out in The General Electric Company's laboratories at Erith.

REFERENCES.

1. Nuclear Products—ERCO, *Report No.* ACF-GCPR-400.
2. Hartnell-Beavis, M. C. A nuclear reactor installation for marine use. *G.E.C. Journal*, Vol. 26 No. 4, pp. 131-139 (Autumn, 1959).

330 kV Oil-filled Cables for Snowy Mountains Hydro-electric Scheme

By A. N. ARMAN, Ph.D., A.C.G.I., M.I.E.E., A.M.I.Mech.E., Fellow A.I.E.E.
Pirelli-General Cable Works Ltd.

THE highest voltage cables to be designed and manufactured in Great Britain have recently been supplied by Pirelli-General Cable Works Ltd. to the Snowy Mountains Hydro-electric Authority, Australia, and successfully installed at the T1 Power Station in the Tumut River Valley. Thus, Pirelli-General are the first British cable makers to complete a commercial installation for 330 kV service.

Transmission of power at 330 kV 3-phase 194 MVA (340 amperes per phase) along a tunnelled route from an underground transformer hall to an outdoor switchyard some 1 600 ft distant has proved a formidable undertaking. When to the existing difficulties are added such diverse factors as extreme climatic conditions, a difference in level of over 200 ft between terminals and an undertaking to install these large cables in single lengths of up to 1 625 ft without intermediate joints, the skill and ingenuity of the Pirelli-General engineers have been fully extended.

The seven cables and their associated accessories were manufactured at the Eastleigh Works and installed under the supervision of Pirelli-General Contracts Engineers. The design of the accessories was undertaken by the Pirelli S.p.A. Milan.

The type of cable installed is illustrated in fig. 1. It takes the form of a copper conductor laid up over a central duct formed as a spiral of aluminium wire of nominally 0·192 in. diameter, the cross-sectional area of the conductor being 0·325 sq. in. The maximum working stress is 130 kV/cm and electrostatic screening of carbon-black papers is provided over the conductor and also over the insulated core. The paper lapping process is carried out on a machine capable of applying up to 200 papers with high mechanical precision and accurately controlled tension, enabling the cable to be insulated in a single pass through the machine (fig. 2). The machine is housed in an air-conditioned enclosure held at low relative humidity to ensure uniform shrinkage in the paper tapes during the subsequent drying process. The cables are lead sheathed and suitably reinforced to withstand the high internal oil pressure. The lower ends of the cables are, for the same reason, provided with longitudinal reinforcement. Anti-corrosion protection is provided overall.

Fig. 1.—330 kV oil-filled cable.

At the station end of the route each cable had to be taken vertically downwards into an oil-filled connecting chamber forming part of its associated main transformer tank (fig. 3). The cable at this end was, therefore, fitted with an oil-immersed terminal (fig. 4) capable of withstanding a continuous pressure of 110 lb/in². Mechanical stability of the insulation for

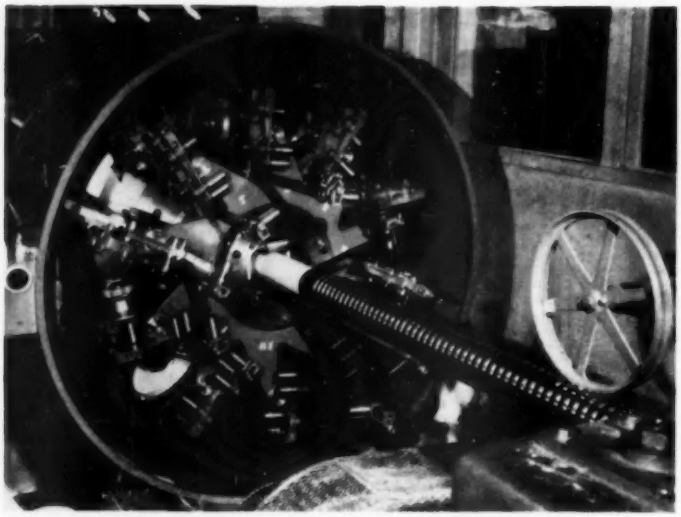


Fig. 2.—Screening tapes being applied to 330 kV oil-filled cable.

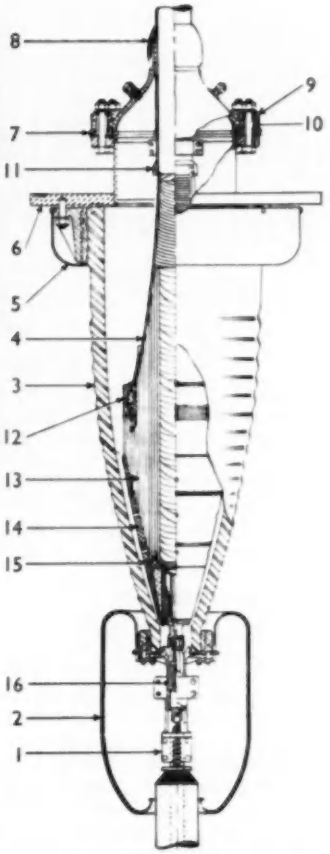


Fig. 4.—330 kV oil-immersed sealing end.

Key:

1. *Clamp connector.*
2. *Corona shield.*
3. *Insulator.*
4. *Wire stress control.*
5. *Bottom corona shield.*
6. *Sealing end flange.*
7. *Insulating spacer.*
8. *Wipe.*
9. *Insulating washer.*
10. *Insulating sleeve.*
11. *Gaiter.*
12. *Epoxy resin insulated stress ring (bottom).*
13. *Paper tube insulation.*
14. *Epoxy resin supports.*
15. *Epoxy resin insulated stress ring (top).*
16. *Plug-in contact.*

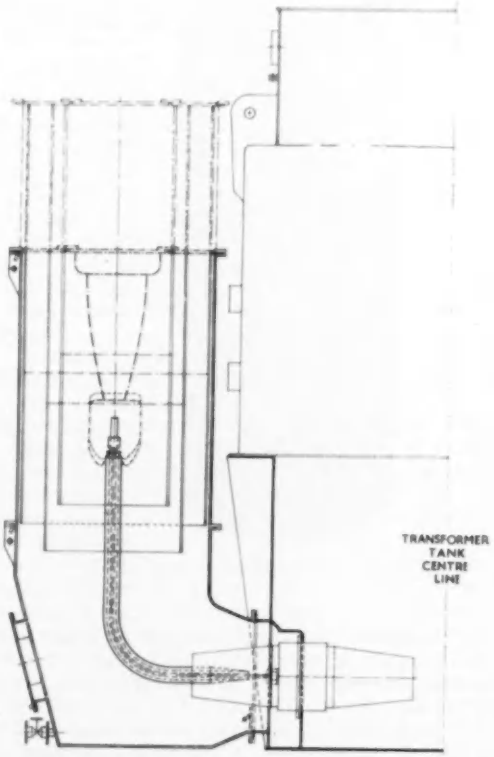


Fig. 3.—Oil-immersed terminal at main transformer tank.

operating in the inverted position was assured by the provision of Epoxy resin supports. Epoxy resin stress-control components were also incorporated and resulted in a considerable reduction in the size of the unit, with consequent economy in the design of the transformer connexion tank. The outdoor terminal (fig. 5) is 11 ft from base plate to top extremity. The porcelain insulator is in two parts which are connected by means of an electrically screened mechanical joint. The internal design of this terminal is in other respects conventional.

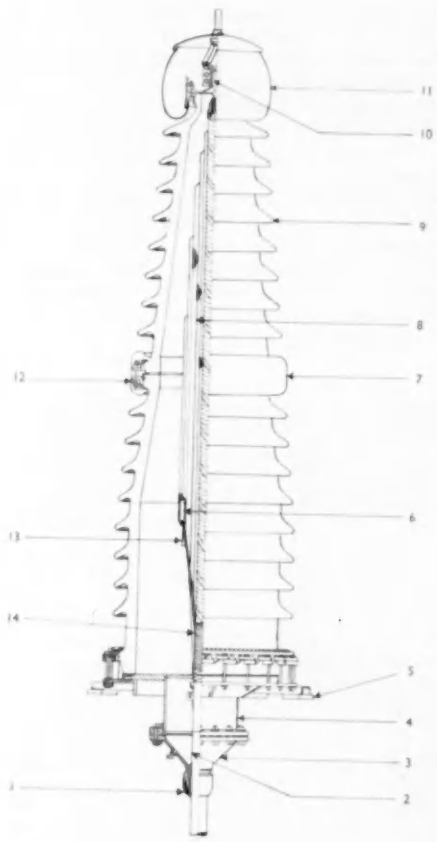


Fig. 5.—330 kV outdoor sealing end.

Key:

1. *Wipe.*
2. *Split copper sleeve.*
3. *End bell.*
4. *Throat assembly.*
5. *Base.*
6. *Stress ring (insulated).*
7. *Stress shield.*
8. *Paper tube insulation.*
9. *Porcelain insulator.*
10. *Plug-in contact.*
11. *Corona shield.*
12. *Articulated ring.*
13. *Gaiter.*
14. *Wire stress control.*

The complete suitability of the system components for service conditions was demonstrated by comprehensive development tests and finally by subjecting a representative installation to the very searching type-test series described below.

The official type-test installation is shown in fig. 6. It consisted of a 100 ft length of production cable, with an outdoor type sealing end and an oil-immersed sealing end and cut into halves and jointed with a straight-through joint. Before assembling, the cable used for the type test was subjected to a bend test of four reverse cycles round a former 11 ft in diameter.

The principal tests, in the order in which they were carried out, are as follows :

1st Impulse Test

Withstand test at the specified level of 1 300 kVp at 85 deg. C nominal temperature (actual 95 deg. C). Wave shape 2·3/55 microseconds.

Long-time a.c. Test

24 h at 475 kV (2·5 × W.V.) at ambient temperature. The object of this test was to prove that the first impulse test had not caused any damage to the insulation.

Loading Cycle and Thermal Stability Test

20 daily cycles of 8 hours heating to 85 deg. C and 16 hours cooling to ambient. Voltage of 286 kV (1·5 × W.V.) continuously applied. Power factor measurements were made daily. At the end of the load cycle test the loading current was adjusted to obtain steady temperature conditions of approximately 90 deg. C. This current was thereafter maintained constant for 6 hours and the perfect stability of the system demonstrated by the unchanged values of temperature and power factor.

A.C. Wet Test

The outdoor sealing end was subjected to an average rate of precipitation of approximately 0·15 in/min (water resistivity of 10 000 ohm/cm) for 30 seconds. The withstand test was carried out at the specified value of 533 kV.

2nd Impulse Test

Withstand test at the specified level at 85 deg. C nominal temperature (actual 95·5 deg. C).

Short-time a.c. Test

15 minutes at 381 kV (2 × W.V.).

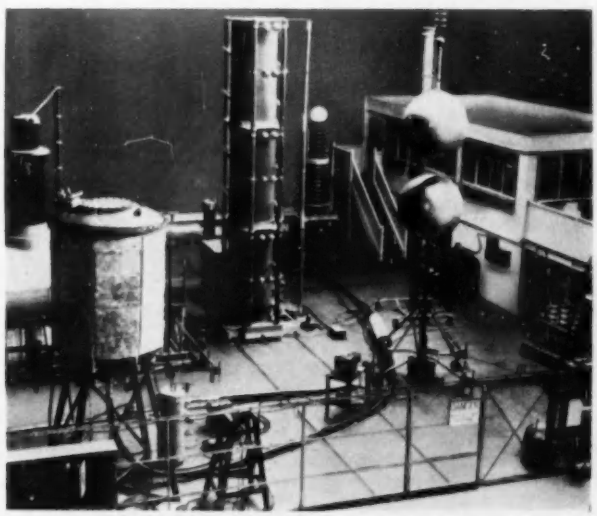


Fig. 6.—Type test arrangement for 330 kV oil-filled cable.

Fig. 7.—330 kV cables on the Tumut River bridge.

Final Impulse Test

The impulse voltage was raised in steps of 50 kV from the specified withstand level of 1 300 kV. Breakdown occurred at 1 500 kV, corresponding to a conductor stress of just over 1 020 kV/cm.

D.C. tests were carried out on a second assembly to prove the soundness of design of the transformer entry chamber, into which the oil-immersed sealing ends are fitted.

Complementary tests included hydraulic tests, at twice the working pressure, on cable and accessories, tests on cable serving, and measurement of cable dielectric thermal resistivity.

The seven cables, which ranged in length between 507 and 543 yards, were pulled from the switch yard end and laid at 1 ft centres in sand-filled troughs in the floor of the tunnel. The sand was specially selected so that its thermal resistance, even when dry, ensured the requisite heat dissipation at the maximum cable loading.

As the switchyard is on the opposite side of the Tumut River to the Power Station, a special bridge had been built over the river to carry the cables (fig. 7). The seven cables were cleated to the bridge on continuous supports, allowance being made for the expansion movements of the cable due to load and to seasonal temperature variations.

The assembly of the outdoor terminals in the switchyard, fig. 8, and the connexions to the oil-feeding pressure tanks presented no special difficulty, but the insertion of the oil-immersed terminals in the transformer connecting chamber involved considerable problems in manipulation. The connecting chambers were filled with oil degasified on site to a condition similar to the oil contained in the cable.

After installation, each phase with its associated terminals was tested at 760 000 volts d.c., using a million volt d.c. mobile test set. Following the test, the transformer connecting tank was emptied, the temporary test barriers below the terminal removed, the transformer connector fitted and the tank again filled with degasified oil.

Fig. 8.—Completed sealing end in the switchyard at T1 power station.

Large-scale planning, knowledge and the most modern equipment combined with arduous work and determination are being contributed to this vast Snowy Mountains Scheme and the Pirelli-General 330 kV oil-filled cable is a most important link in this complex chain.

TECHNICAL LITERATURE

A digest of recent articles and papers by members of the G.E.C. and its associated companies

DISPERSION CURVES FOR A HELIX IN A GLASS TUBE (774).*

By D. T. Swift-Hook (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 11, 1958.

The dispersion equations giving the variation of velocity of propagation with frequency for a sheath helix (a thin cylinder conducting only in a helical direction) inside a dielectric tube are obtained, and, from these, dispersion curves are plotted for various ranges of the parameters (tube diameter, permittivity, wall thickness, etc.).

Simple approximate formulae are derived and are used to discuss the general characteristics of the curves, and a structure is given which would be non-dispersive over a very large frequency range.

A NEW TYPE OF WATER-VAPOUR REPLENISHER AND ITS APPLICATION TO A T.R. SWITCH (775).*

By T. L. Dutt and W. I. Moore (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 10, *May*, 1958.

A low-pressure water-vapour replenisher is described for use in a t.r. switch. The water-vapour pressure exerted by the replenisher is sensibly constant over the temperature range −20 deg. C to +120 deg. C.

Measurements of the physical properties of the replenisher are discussed with reference to the theory of adsorption advanced by Polanyi.

THE PERIODICALLY-LOADED TRAVELLING-WAVE MULTIPLE-BEAM KLYSTRON (776).*

By V. A. Heathcote, P. A. Lindsay, J. Barraclough and J. R. Newby (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 12, 1958.

The periodically-loaded travelling-wave klystron (p.l.t.w.k.) is a fast-wave multi-beam microwave amplifier for very high power, having an operating bandwidth greater than 10 per cent.

A theoretical investigation has been carried out for small-signal conditions, relativistic corrections being included. Optimum conditions for the various parameters affecting the operation have been determined, and the results are presented in a series of contour diagrams.

SOME ASPECTS OF THE DESIGN OF A HELICAL COUPLER FOR A TRAVELLING-WAVE TUBE OPERATING IN THE 2Gc/s BAND (778).*

By P. A. Lindsay and K. D. Collins (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 11, 1958.

The paper describes the development of a helical coupler designed for use with travelling-wave tubes operating in the 1 700-2 300 Mc/s band. The theory of operation of helical couplers is briefly summarized, and the design and construction of the coupler are then dealt with. An outline of the measuring techniques employed in the course of its development is also given.

ELASTIC AND PLASTIC PROPERTIES OF CARBON AND GRAPHITE (785).*

By H. W. Davidson and H. H. W. Losty (Research Laboratories).

Mechanical Properties of Non-Metallic Brittle Materials, Butterworth's Scientific Publications.

An attempt has been made to rationalize the elastic and plastic properties of graphite and carbon in terms of the movement of layer planes within the graphite crystallites. It has proved possible to do this without direct reference to the gross grain structure of the materials. The mechanism accounts qualitatively for the behaviour on graphitization and neutron irradiation. It is also possible to rationalize the changes that occur on elevating the test temperature.

DESIGN AND PERFORMANCE OF A NEW LOW-NOISE TRIODE FOR USE UP TO 1 000 Mc/s (786).*

By A. D. Williams and D. C. Gore (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 106, *Part B Supplement No.* 25, *January*, 1959.

The paper outlines the factors governing the design of a simple glass-base u.h.f. amplifier valve and considers the circuits in which it can be used.

The design of such a valve is described, together with the special techniques which are necessary to obtain reproducibility with inter-electrode clearances of only 40 microns.

Detailed information is given on the stability, noise performance and gain-bandwidth product of the valve over the u.h.f. band.

MEASUREMENT OF DISORDER IN ZINC AND CADMIUM SULPHIDES (794).*

By M. A. Short and E. G. Steward (Research Laboratories).

The American Mineralogist, Vol. 44, *pp.* 189-193, 1959.

It is well known that the effect of mechanical work, such as grinding or the application of pressure, is progressively to convert zinc sulphide of initially hexagonal structure towards the cubic structure. In the course of an investigation into the effect of grinding on the structure and luminescence of zinc and zinc-cadmium sulphides, it became necessary to measure the relative amounts of cubic and hexagonal stacking after various times of grinding.

EVAPORATION OF THORIUM FROM CARBURIZED THORIATED TUNGSTEN CATHODES (799).*

By R. O. Jenkins and W. G. Trodden (Research Laboratories).

British Journal of Applied Physics, Vol. 10, *pp.* 10-15, *January*, 1959.

The evaporation of thorium from carburized thoriated tungsten cathodes is shown experimentally to be approximately the same as that from similar uncarburized cathodes at the same temperature. The thorium in a carburized cathode is, however, produced continuously at an adequate rate at the operating temperature of 2 000 deg. K by reduction

of the thoria by the tungsten carbide. The uncarburized cathode operates on a reserve of thorium built up by flashing at 2 800 deg. K at which temperature the tungsten reduces some of the thoria. These reactions have been examined by thermochemistry and it is shown that thorium diffuses to the surface of both types of cathode by a mechanism relatively insensitive to temperature.

PERIODIC ELECTROSTATIC BEAM FOCUSING (801).*

By H. A. C. Hogg (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 12, 1958.

Two new methods of focusing a strip electron beam by means of periodic electrostatic fields are described. Focusing is obtained with all conductors of the periodic structures at the same direct voltage—a condition which simplifies construction and operation. Wave crests in an undulating beam trajectory are made to coincide with regions of maximum axial r.f. field, giving good coupling between the two.

MEASURING MODULATION NOISE FROM A HIGH-POWER C.W. KLYSTRON AMPLIFIER (803).*

By D. E. T. F. Ashby and R. B. Dyott (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 12, 1958.

The noise spectrum of a high-power klystron amplifier shows that, as well as the r.f. shot noise, the power output contains modulation sidebands caused by variations in gain associated with low-frequency fluctuations.

Modulation noise can be caused by any low-frequency fluctuations in the system, e.g. power supply ripple, microphony, or spurious beam oscillations. Apparatus for investigating these effects includes a panoramic spectrum analyser for observing and correlating the r.f. noise associated with the carrier and the video noise fluctuations.

A new method of noise detection is described which uses a coaxial diode at high power level instead of the conventional low-power crystal detector.

A STUDY OF THE REACTIONS OF GRAPHITE WITH CARBON DIOXIDE WITH REFERENCE TO GAS-COOLED NUCLEAR REACTORS (804).*

By T. B. Copestake, H. W. Davidson and B. L. Tonge (Research Laboratories).

Journal of Applied Chemistry, Vol. 9, *pp.* 74-84, *February*, 1959.

The reaction of graphite and carbon dioxide is discussed in relation to the performance and safety of gas-cooled graphite-moderated nuclear reactors. Reaction is promoted by reactor radiation but this radiation-induced process is unlikely to be temperature dependent. The limiting temperature for operating the system graphite-carbon dioxide is, therefore, probably set by the thermal reaction. A wide variety of experimental means has been used to examine the thermal reaction and it is concluded that gasification of carbon by carbon dioxide is unlikely below temperatures of 600 deg.

A WIDE-BAND MULTI-WAY ELECTRONIC SWITCH FOR USE AT MICROWAVE FREQUENCIES (805).*

By S. M. Hamberger (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 10, *May*, 1958.

A wide-band four-way switch is described in which any of four coaxial lines may be coupled to a fifth. The switching is accomplished by bridging a gap in the inner conduction of a coaxial line with the conducting plasma which follows a d.c. pulsed discharge in a rare gas. By using the cool electrons in the afterglow for the r.f. conductivity, low-loss propagation is achieved with no apparent excess noise generation.

CONSTRUCTIONAL AND DESIGN DIFFICULTIES OF WIDE-BAND HIGH-POWER PULSED TRAVELLING-WAVE TUBES IN THE 10 Gc/s REGION (807).*

By C. H. Dix and R. G. Robertshaw (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 10, *May*, 1958.

The paper describes some of the difficulties met in the development of a pulsed travelling-wave amplifier having a maximum power in the region of 1 kW and gain greater than 30 dB over the frequency band 7·5-11·5 Gc/s. This is a considerably higher power level than has been previously attempted in this country with a helix-type tube, and the parts of the development which are described are, in general, only those in which difficulty was met due to the particular combination of high power, high frequency and broad bandwidth.

FREQUENCY PUSHING IN CROSSED-FIELD OSCILLATORS (810).*

A Comparison between the C.W. Magnetron and the Magnetron-Type Backward-Wave Oscillator by R. I. Buick, A. Reddish and I. J. Zucker (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 10, *May*, 1958.

Experimental results showing the effect of anode current on the frequency of crossed-field oscillators are presented. The results for M-type backward-wave oscillators are shown to be qualitatively explained simply by taking into account the potential deresion due to the presence of the electron beam.

MAGNETIC OSCILLATIONS IN ELECTRON BEAMS (811).*

By R. H. C. Newton (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 11, 1958.

The basic equations governing the small-signal oscillations in a cylindrical beam of electrons are studied, and it is shown that, in addition to the usual space-charge solution, there exists another, separate, infinite set of modes which are much more closely associated with the cyclotron angular frequency, ω_c, of the collimating magnetic field.

PHOTO-ETCHING MOLYBDENUM FOIL (812).*

By H. A. C. Hogg (Research Laboratories).

The Proceedings of the Institution of Electrical Engineers, Vol. 105, *Part B Supplement No.* 11, 1958.

The production of an O-band slow-wave circuit for a backward-wave oscillator, using a photo-etching technique, is described. Details of the necessary apparatus are given, and the difficulties met in etching molybdenum are discussed.

BONDING IN CARBIDES, SILICIDES, AND BORIDES (816).*

By D. A. Robins (Research Laboratories).

Powder Metallurgy, No. 1/2, 1958.

The hypothesis that many of the properties of the transition metals, their alloys, and their compounds can be understood in terms of a relationship between the co-ordination of the metal atoms and the number of bonding electrons per atom, is applied to the carbides, silicides, and borides of the transition metals of Groups IVA, VA, and VIA. The crystal structure and stability of the carbides can be satisfactorily explained on the basis of electron concentration, but a complete understanding of the bonding in the silicides and borides is more difficult.

ENERGY LOSS PROCESSES IN FERROELECTRIC CERAMICS (818).*

By B. Lewis (Research Laboratories).

Proceedings of the Physical Society, Vol. LXXIII, p. 17, 1959.

By a study of ageing effects in which permittivity, elastic compliance and the electrical and mechanical loss coefficients decrease with time, the principal ferroelectric loss process in low fields is identified as microhysteresis associated with small-amplitude domain boundary movement. Larger fields produce macrohysteresis effects due to large-scale boundary movement, and the permittivity, compliance and loss coefficients are increased.

SOME NEW TECHNIQUES FOR PREPARING SMALL QUANTITIES OF HIGH PURITY REFRACTORY METALS (820).*

By D. A. Robins and I. Jenkins (Research Laboratories).

Plansee Proceedings, 1958.

A number of new techniques are described for removing trace impurities, and, in particular, interstitial elements from high-melting-point metals such as tantalum and molybdenum. Apparatus is described for solid state purification both by resistance heating and electron bombardment and apparatus for liquid state purification by zone refining is also described. The relative merits of solid state and liquid state purification are discussed.

ECHO-DISTORTION IN FREQUENCY-MODULATION (822).*

Frequency-Division-Multiplex Trunk Radio Systems. By R. G. Medhurst (Research Laboratories).

Electronic and Radio Engineer, Vol. 36, *pp.* 253-259, *July*, 1959.

The level of intermodulation distortion generated in an f.m., f.d.m. trunk radio system by a small echo depends on the echo amplitude and delay, on the phase relation between the wanted carrier and the echo carrier, and on the parameters of the modulation ; i.e. the maximum and minimum modulating frequencies, the r.m.s. deviation and the base-band spectral distribution. Numerical evaluation for the important case of top channel distortion has been carried out on a Hollerith Hec.2M digital computer, the results being presented as general curves covering a wide range of parameter values.

THE DIFFERENTIAL THERMAL ANALYSIS OF SIMPLE GLASS BATCH REACTIONS (823).*

By L. F. Oldfield (Research Laboratories).

Compte Rendu du Symposium sur la Fusion du Verre, Brussels, October 6-10, 1958.

A new apparatus for the differential thermal analysis of glass batch reactions up to 1 200 deg. C is described with special reference to the crucible assembly. Some reactions occurring in the systems, $Na_2CO_3 - SiO_2$, $K_2CO_3 - SiO_2$, $Na_2CO_3 - CaCO_3 - SiO_2$ and $Na_2CO_3 - B_2O_3 - SiO_2$ have been investigated. The influence of batch particle size and refining agents on the melting behaviour of simple batches, as shown by D.T.A., is described.

THE ELECTRICAL CONDUCTIVITY AND HALL COEFFICIENT OF BISMUTH TELLURIDE (827).*

By B. Yates (Research Laboratories).

Journal of Electronics and Control, Vol. 6, *No.* 1, *p.* 26, *January*, 1959.

This paper describes the variation of the electrical conductivity and Hall coefficient of a number of specimens of Bi_2Te_3 over a wide range of doping concentration. A detailed examination of these quantities, over the temperature range 1·3 to 660 deg. K, has revealed the existence of trends which vary systematically with the degree of doping, although anomalies exist within this scheme. It is shown that an impurity band mechanism may operate in n-type Bi_2Te_3.

THERMIONIC PROPERTIES OF THORIUM DEPOSITS ON CONTROL GRID MATERIALS (831).*

By J. A. Champion (Research Laboratories).

British Journal of Applied Physics, Vol. 10, *pp.* 71-74, *February*, 1959.

Experiments are described in which the emission is measured from thin films of thorium deposited on different platinum-molybdenum phases of approximate composition *Pt*, Pt_3Mo, Pt_2Mo, Pt_3Mo_2 and *Mo*. The emission from all the platinum phases is considerably lower than that from pure molybdenum. The lowest emission was observed with the Pt_3Mo phase. The emission from thorium deposited on to the Pt_3Mo_2 phase decays rapidly at temperatures of 1 300 deg. C and above, whereas that from similar deposits on molybdenum does not.

THE FREQUENCY CHARACTERISTICS OF HYBRID JUNCTIONS AS PHASE DIVIDERS AND DUPLEXERS (834).*

By R. Levy (Applied Electronics Laboratories).

Electronic and Radio Engineer, Vol. 36, *pp.* 308-312, *August*, 1959.

A review of the existing theoretical analyses of hybrid junctions is presented to show how the phase difference between the waves from the two output arms varies with frequency. It is shown that this variation is very small in the case of all well-matched 90° hybrid junctions but, for the hybrid ring, a large variation in phase difference occurs due to asymmetry of the junction.

THEORETICAL TRANSPORT COEFFICIENTS FOR POLAR SEMICONDUCTORS (836).*

By R. T. Delves (Research Laboratories).

Proceedings of the Physical Society, Vol. LXXIII, p. 572, 1959.

The mobility, thermoelectric power and weak field Hall coefficient have been calculated when the charge carriers of a polar semiconductor are scattered by an optical mode of vibration of the lattice. The collision operator derived by Fröhlich, and Howarth and Sondheimer was used, and the Boltzmann transport equation was integrated directly on an electronic computer.

THE THERMOELECTRIC POWER OF A SEMICONDUCTING DIAMOND (837).*

By H. J. Goldsmid, C. C. Jenns and D. A. Wright (Research Laboratories).

Proceedings of the Physical Society, Vol. LXXIII, p. 393, 1959.

The thermoelectric power of a p-type semiconducting diamond has been measured in the temperature range 220 deg. K to 700 deg. K. After subtracting an electronic component, estimated from the previous Hall effect measurements on the sample, it has been possible to determine the phonon-drag component of the thermoelectric power.

THE GAIN OF TRAVELLING-WAVE FERROMAGNETIC AMPLIFIERS (842).*

By P. J. B. Clarricoats (Applied Electronics Laboratories).

I.E.E. Monograph No. 334*E*.

The paper describes a general perturbation method for determining the gain of travelling-wave ferromagnetic amplifiers. By use of the method, the gain is determined for an amplifier employing a circular waveguide and an axial ferrite rod of small cross-section. The efficiency of such an amplifier is shown to be low, and a practical version would demand the use of larger rod cross-section and/or a slow-wave structure.

EVAPORATION OF BARIUM FROM CATHODES IMPREGNATED WITH BARIUM-CALCIUM-ALUMINATE (843).*

By I. Brodie, R. O. Jenkins and W. G. Trodden (Research Laboratories).

Journal of Electronics and Control, Vol. 6, No. 2, p. 149, February, 1959.

The evaporation of barium from cathodes impregnated with barium-calcium-aluminate, $3BaO \cdot Al_2O_3 2CaO$ has been observed during the life of cathodes made with various thicknesses of two types of porous tungsten. The slow decay observed in thin cathodes of very porous tungsten appears to be due mainly to the reaction producing barium being retarded by the reaction products accumulating at the interface between the tungsten and the impregnant. The more rapid decrease for thick cathodes of lower porosity is due to the escape of barium becoming the limiting factor.

THE REDUCTION OF THE PERMEABILITY OF GRAPHITE (845).*

By D. A. Boyland (Research Laboratories).

G.E.C. Atomic Energy Review, Vol. 2, No. 1, March, 1959.

The low neutron cross-section and the neutron-moderating properties of graphite make it a very important material in the field of nuclear energy.

The porous nature of normal graphite, however, prevents its being used to contain liquids and gases. To reduce this porosity, graphite is frequently impregnated with resinous substances or polymerizing materials. Methods of reducing the permeability of reactor-quality graphite and ensuring that the impregnated material will remain stable at temperatures of 800 deg. C or more, are described in this article.

COAXIAL-CABLE PERFORMANCE (848).*

Determination of Sine-Squared Pulse Response. By W. A. Cameron (Research Laboratories).

Electronic and Radio Engineer, Vol. 36, No. 9, pp. 349-352, September, 1959.

The transmission of a transient waveform through a cable causes a decrease in amplitude of the waveform and an increase in its effective width. Thus the measurement of impedance regularity of a cable by pulse reflection requires a knowledge of the response of the cable to the impulse used. This can be measured experimentally using multiple reflections in a short length of cable, or calculated from a knowledge of the pulse shape.

THE REMOVAL OF INTERNAL POROSITY IN COPPER (851).*

By B. Clapson and D. A. Robins (Research Laboratories).

Powder Metallurgy, No. 3, 1959.

Observations on the removal of internal porosity in copper have shown the importance of grain boundaries in the sintering process. Grain boundaries act as strong vacancy sinks in contrast to twin boundaries and dislocations, which apparently do not absorb a large number of vacancies. It is concluded that, in copper, the mechanism of sintering is that of the diffusion of vacancies to the grain boundaries, where they are destroyed by the progressive removal of planes of atoms adjacent to the boundaries.

THE APPLICATION OF THE FLAME PHOTOMETER AND THE SPECTROGRAPH TO THE ANALYSIS OF A SODA-LIME GLASS (855).*

By R. J. Powell and Janet Todd (Research Laboratories).

Transactions of the Society of Glass Technology, Vol. XLIII, pp. 73T-85T, 1959.

The determination of alkalis and calcium in glass by flame photometry and of calcium, aluminium, and magnesium by spectrography has been investigated. Two flame photometers were used: an Evans Electroselenium Ltd. filter photometer and a flame spectrometer.

The determination of calcium, magnesium, and aluminium by a spectrographic porous cup technique has been studied and some preliminary investigation has been carried out into the use of solid samples for the spectrograph.

THE DETERMINATION OF POTASSIUM OXIDE IN GLASS (856).*

By H. J. Cluley (Research Laboratories).

Transactions of the Society of Glass Technology, Vol. XLIII, pp. 62T-72T, 1959.

Conventional analytical methods for potash in glass, based on gravimetric determination as perchlorate, platinichloride or cobaltinitrite, have various disadvantages.

In previously published work the author has shown that precipitation of potassium as the tetraphenylboron derivative has advantages over the older methods. This method has now been in use for three years and has been successfully applied to a variety of glasses.

Recent work has shown that the determination may be shortened still more by using a volumetric finish. A limited trial of the volumetric method on four glasses has given results generally within 0·1 per cent of the gravimetric figure.

STUDIES IN ANCIENT GLASSES AND GLASSMAKING PROCESSES PART VI. THE COMPOSITION AND PHYSICAL CHARACTERISTICS OF THE GLASSES OF THE PORTLAND VASE.

By W. E. S. Turner *and*

AN INVESTIGATION OF ANCIENT OPAL GLASSES WITH SPECIAL REFERENCE TO THE PORTLAND VASE (861).*

By H. P. Rooksby (Research Laboratories).

Journal of the Society of Glass Technology, Vol. XLIII, pp. 262T-288T, 1959.

The cameo-type vase known as the Portland Vase, with a dark blue body decorated by sculptured reliefs cut from an overlay of opal glass, is probably the most famous and highly valued of all ancient glass objects. Until 1951 the chemical composition of the two glass components had remained conjectural; but in that year the Corning Glass Company made a semi-quantitative analysis, spectrographically, of a flake of the body glass, and later (1955) H. Moore published a spectral transmission curve of a similar flake. The much more comprehensive and precise work now described, carried through with the collaboration of a number of expert investigators, has resulted in the quantitative determinations of eleven constituents of the dark blue body glass and ten of an opal glass which matches that on the vase.

ALTERNATIVES TO THE WIEN BRIDGE.

By J. F. Young (Switchgear Division, Witton).

Wireless World, Vol. 65, pp. 92-95, February, 1959.

The characteristics of the Wien bridge used in resistance-capacitance oscillators are considered, and it is shown that an identical frequency response can be obtained from other circuits. While these alternatives have been known for some time, they have been little used in oscillators. Circuits giving an improved response and an oscillator using one of these are described.

A SIMPLE VERY-LOW-FREQUENCY OSCILLATOR.

By J. F. Young (Switchgear Division, Witton).

Electronic Engineering, Vol. 31, pp. 218-220, April, 1959.

The usual methods of amplitude stabilization of resistance-capacitance oscillators are frequency sensitive. In the simple oscillator described a Zener diode limits the amplitude and the resulting harmonics are filtered out by a selective circuit which also controls the frequency of oscillation. A reasonable waveform can therefore be obtained even at very low frequencies.

A TRANSISTOR CHARACTERISTIC CURVE TRACER.

By J. F. Young (Switchgear Division, Witton).

Electronic Engineering, Vol. 31, *pp.* 330-336, *June*, 1959.

A dekatron is used to develop a stepped voltage controlling the base current of the transistor under test. At each step a half-sinusoidal voltage is applied to the transistor and the resulting collector current is plotted against voltage on an external oscilloscope. A series resistor provides the current signal and limits the transistor dissipation. The unit can also be used to plot the characteristics of normal or of Zener diodes.

TRANSISTORIZED PULSE AMPLIFIER (862).*

By J. N. Barry and D. M. Leakey (Research Laboratories).

Electronic and Radio Engineer, Volume 36, *pp.* 200-207, *June*, 1959.

The article describes the design of a transistorized pulse amplifier for use with diode logic circuits. With an effective overall gain exceeding 10, the total rise- and fall-times obtainable are each better than 0·05 microsecond, although there is also a short delay between the input and output pulses. The circuit employs two high-frequency drift transistors of a type specially developed for switching applications. Some of the problems associated with the use of such transistors are discussed briefly.

MEASUREMENT OF MAGNETIC FLUX DENSITY BY PARAMAGNETIC RESONANCE (863).*

By C. P. Allen and M. Sherry (Research Laboratories).

Journal of Electronics and Control, Vol. 6, *No.* 3, *p.* 264, *March*, 1959.

This paper describes a method of measuring magnetic flux density to a high degree of accuracy using a very simple coaxial line apparatus. The method relies on measurement of the paramagnetic resonance at microwave frequencies in an organic compound containing unpaired electron spins. Using this technique magnetic flux density may be measured to an absolute accuracy of ±0·06 per cent and variations in the flux density may be measured of approximately ±0·006 per cent. The method is suitable for flux densities ranging from a few hundred to some thousands of gauss.

A DELTA MODULATION SYSTEM USING JUNCTION TRANSISTORS (864).*

By B. E. Williams (Research Laboratories).

Electronic Engineering, Vol. 31, *No.* 381, *p.* 674, *November*, 1959.

A delta modulation system, operating at a digit frequency of 14 kc/s, is described which provides a simplex speech link with good intelligibility. The equipment has only one manual control, the press-to-talk switch, other adjustments being preset or made automatically. The receiver regenerates the incoming signal by voltage and time slicing before feeding the decoder. The equipment will work satisfactorily over a wide range of ambient temperatures and is suitable for use over equalized lines or radio links. A power supply of between 6 and 12 V is required.

DISCOMFORT GLARE IN INTERIOR LIGHTING INSTALLATIONS—COMPARISON OF APPRAISALS AND CALCULATED VALUES (866).*

By E. Rowlands (Research Laboratories).

Light and Lighting, Vol. 52, *No.* 3, *pp.* 102-107, *March*, 1959.

The results of appraisal tests of direct discomfort glare in interior lighting installations are compared with those calculated by the Harrison-Meaker method and by the formula suggested at the CIE meeting in 1955 with terms for the immediate background luminance and the positions of the sources. The comparison shows a marked disagreement for some installations, and suggests that a different approach to the evaluation of direct discomfort glare should be made.

THE FARADAY EFFECT IN ANISOTROPIC SEMICONDUCTORS (870).*

By I. G. Austin (Research Laboratories).

Journal of Electronics and Control, Vol. 6, *No.* 3, *p.* 271, *March*, 1959.

The theory of the Faraday effect in semiconductors is extended to uniaxial crystals with spheroidal energy surfaces, using the classical Drude-Zener theory. Expressions applicable at infra-red frequencies are given and used to discuss preliminary measurements on Bi_2Te_3.

*** A limited number of reprints is available of those papers marked with an asterisk. Copies may be obtained on application to the Editor, G.E.C. Journal, Magnet House, Kingsway, W.C.2.**